केन्द्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation,

Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

Raipur District
Chhattisgarh

उत्तर मध्य छत्तीसगढ़ क्षेत्र, रायपुर

North Central Chhattigarh Region, Raipur

AQUIFER MAPS AND GROUND WATER MANAGEMENT PLAN, RAIPUR DISTRICT, CHHATTISGARH

(04 BLOCKS- ARANG, ABHANPUR, TILDA & DHARSIWA)

C O N T R I B U T O R S'

Principal Author

Priyanka B. Sonbarse	:	***Junior Hydrogeologist / Scientist-B***

Supervision & Guidance

A K Biswal	**:**	Senior Hydrogeologist/ Scientist-E

Groundwater Exploration 2020-21, Raipur district

Priyanka B. Sonbarse	**:**	**Scientist-B**

Chemical Analysis

Rakesh Dewangan	:	Scientist B (Chemist)
Anita Bind	:	STA (Chemical)

Section Finalization / Map Digitization

Priyanka B. Sonbarse	:	Scientist-B
T S Chauhan	:	Draftsman

FOREWORD

Raipur district is considered to be one of the leading districts of Chhattisgarh State owing to its political, industrial and mining activities. It is also famous for its irrigation practices and agriculture productivity, especially in paddy crop. Though the agriculture practices are still traditional being rainfed, it is one of the foremost districts of the country in production of both Kharif and Rabi crops. Because of the availability of surface water resources supported by a well spread canal network, about 76 % of the total cultivated area gets supplemental irrigation.

With the growth in population and increase in urban areas the demand of water in various sectors, like agriculture, industry and urban sectors, is continuously rising, ultimately exerting tremendous pressure on water resources. Due to the unpredictable nature and uneven distribution of monsoon the productivity of kharif crop is severely affected every year. During summer months most of the urban and rural areas face drinking water scarcity while the production of water-based industries is hampered due to the unavailability of this essential commodity. The need-based development and judicious management of the vast untapped ground water resources in the district may serve as a safe and sustainable source of water for domestic, irrigation and industrial purposes.

Wide variation in hydrogeological properties of the rocks has manifested in the uneven distribution of aquifers, as well their yielding properties in the district. In general, the dug wells, dug cum borewells and borewells are the structures through which the ground water is being exploited except in the areas covered by thin alluvium / laterite, where gravel packed wells are feasible. Proper siting and designing of the abstraction structure is the main factor affecting the management and development of ground water resources, which requires an integrated approach, and thorough knowledge of hydrogeology of the area.

The report titled "A REPORT ON AQUIFER MAPS AND GROUND WATER MANAGEMENT PLAN OF RAIPUR DISTRICT, CHHATTISHARH" is prepared by ***Ms. Priyanka B. Sonbarse, Scientist-B*** *under supervision of Sh. A.K Biswal, Scientist-E. This report contains the results and findings of hydrogeological surveys, investigations, and ground water exploration, so far carried out by the Central Ground Water Board in the district. This report is expected to be the milestone for further development and management of the valuable ground water resource in the district. I appreciate the concerted efforts put by the author to make it possible to bring the report in its present shape. I hope this report will no doubt be useful and worthy for the benefit of Raipur district and would be a useful document for academicians, administrators, planners and all the stakeholders in ground water.*

Though utmost care has been taken to minimize the errors, some errors may have inadvertently crept in. It is expected that these mistakes will be taken in the proper spirit.

Dr. Prabir K. Naik
(Regional Director)

कार्यकारी सारांश

रायपुर जिला 2892 वर्ग किमी के क्षेत्र को कवर करता है और 20°56'56'' से 21°37'30'' के उत्तरी अक्षांशों और 81°32'13'' से 82°11'50'' के पूर्वी देशांतरों के बीच स्थित है। भारत के सर्वेक्षण में डिग्री शीट नंबर 64G, H, K, L और 65I। और 4 तहसीलों और 4 ब्लॉकों में विभाजित है, जिसमें 4 शहरी केंद्र और 485 गांव शामिल हैं। भू-आकृति विज्ञान की दृष्टि से जिले में परिपक्व प्रकार की भू-आकृतियाँ हैं और इसे मोटे तौर पर दो प्रमुख भू-आकृतिक इकाइयों में विभाजित किया जा सकता है। ये हैं 1. प्रोटेरोज़ोइक शेल- चूना पत्थर डोलोमाइट क्षेत्र द्वारा निर्मित विच्छेदित पेडिप्लेन। 2. सिवनाथ-महानदी जलोढ़ द्वारा निर्मित जलोढ़ मैदान। भूमि उपयोग पैटर्न इंगित करता है कि कुल क्षेत्रफल का 97% कृषि भूमि के कब्जे में है।

जिले में 65 बरसात के दिनों के साथ 1240 मिमी की सामान्य वर्षा होती है। जिले में उष्णकटिबंधीय जलवायु की स्थिति है। पूरा जिला महानदी बेसिन के अंतर्गत आता है। मुख्य सहायक नदियाँ सिवनाथ, जोंक और तेल हैं।

जिला मुख्य रूप से छत्तीसगढ़ सुपर ग्रुप के तलछटी संरचनाओं के अंतर्गत आता है, नदी के किनारे को छोड़कर, जहां हाल ही में जलोढ़ जमा किया गया है।

जलोढ़, लेटराइट और अपक्षय मेंटल में भूजल जल स्तर की स्थिति में होता है। यह गहरे खंडित और गुफाओं वाले जलभृतों में सीमित परिस्थितियों में अर्ध-सीमित परिस्थितियों में होता है। जिले में जल स्तर की गहराई प्री-मानसून में 1.9 से 18.54 mbgl, मानसून के बाद की अवधि में 0.77 से 10 mbgl तक भिन्न होती है। उतार-चढ़ाव 1.12 से 14.1 मीटर तक भिन्न होता है। केंद्रीय भूजल बोर्ड द्वारा किए गए अन्वेषण ने संभावित खंडित क्षेत्रों की उपस्थिति को 130 एमबीजीएल तक कम करने का संकेत दिया है। जिले में बोरवेल की इष्टतम वांछनीय गहराई 50 और 90mbgl के बीच है। क्षेत्र के गहरे जलभृत का दोहन करने वाले बोरवेल की उपज 13lps तक जाती है। अन्वेषण डेटा इंगित करता है कि जिले में चंडी चूना पत्थर की संरचनाएं सबसे अधिक संभावित हैं।

उथले और गहरे जलभृतों के भूजल की रासायनिक गुणवत्ता अच्छी है और यह पीने, सिंचाई और औद्योगिक उद्देश्यों के लिए उपयुक्त है।

जिले में वार्षिक निकालने योग्य भूजल रिचार्ज (Ham) 42499.6ham है। भविष्य में उपयोग के लिए शुद्ध भूजल उपलब्धता 13585.14ham है। सभी उद्देश्यों के लिए वर्तमान वार्षिक भूजल निकासी 28,840.83 हैम है जिसमें से 20,776.86 हैम सिंचाई के लिए है। जिले में भूजल निष्कर्षण का समग्र चरण 68.23 प्रतिशत है। धारसीवा ब्लॉक क्रिटिकल कैटेगरी में आता है।

प्री-मानसून प्रवृत्ति से पता चलता है कि 43% कुओं में जल स्तर में 0.6 से 5.4 सेमी/वर्ष की वृद्धि देखी गई है। इसी तरह, मानसून के बाद की प्रवृत्ति से पता चलता है कि 71% कुओं में 0.1 से 4.5 सेमी/वर्ष की गिरावट की प्रवृत्ति दिखाई देती है और 29% कुओं में क्रमशः 0.2 से 1.3 सेमी/वर्ष की वृद्धि की प्रवृत्ति दिखाई देती है।

जिले में भूजल ज्यादातर खोदे गए कुओं और बोरवेल के माध्यम से विकसित किया जाता है। जिले में लगभग 90% ग्रामीण और 60% शहरी पेयजल आपूर्ति योजनाएँ भूजल पर निर्भर करती हैं।

EXECUTIVE SUMMARY

Raipur district covers an area of 2892 sq.km and lies between north latitudes of 20°56’56’’ to 21°37’30’’ and east longitudes 81°32’13’’ to 82°11’50’’ falling within survey of India Degree sheets No. 64G, H, K, L and 65I. and is divided into 4 tehsils and 4 blocks, comprising 4 Urban Centers and 485 villages. Geomorphologically the district is having matured type of landforms and can be broadly divided into two prominent geomorphic units. These are 1. Dissected pediplain made by Proterozoic shale-limestone dolomite area. 2. Alluvial Plain formed by Seonath-Mahanadi Alluvium. The land use pattern indicates that 97 % of the total area is occupied by the agricultural land.

The district receives a normal rainfall of 1240 mm with 65 rainy days. The district has tropical climatic conditions. Entire district falls under Mahanadi River Basin. The main tributaries are Seonath, Jonk& Tel.

The district is mainly underlain by sedimentary formations of Chhattisgarh super group except along riverbanks, where the recent alluvium is deposited.

Ground water occurs under water table condition in alluvium, laterite and weathered mantle. It occurs under semi confined to confined conditions in the deeper fractured & cavernous aquifers. The depth of water level varies in the district varies from 1.9 to 18.54 mbgl in pre-monsoon, from 0.77 to 10 mbgl in post-monsoon period. The fluctuation varies from 1.12 to 14.1 m. The exploration by Central Ground Water Board has indicated the presence of potential fractured zones down to 130 mbgl. The optimum desirable depth of bore wells in the district is between 50 and 90mbgl. The yield of bore wells tapping the deeper aquifer of the area goes up to 13lps. The exploration data indicates that Chandi limestone formations is the most potential in the district.

The chemical quality of the ground water of shallow as well as deeper aquifers is good and is suitable for drinking, irrigation and industrial purposes.

the Annual Extractable Ground Water Recharge (Ham) in the district is 42499.6ham. The Net Ground Water Availability for future use is 13585.14ham. Current Annual Ground Water Extraction for all purposes is 28,840.83ham out of which 20,776.86ham is for irrigation. The overall Stage of Ground Water Extraction in the district is 68.23%. The Dharsiwa blocks falls in critical category.

The Pre-monsoon trend shows that 43% of wells show rise of water level to the tune of 0.6 to 5.4 cm/yr. Similarly, the Post-monsoontrend shows 71 % of wells show falling trend to the tune of 0.1 to 4.5 cm/year &29% of wells show rising trend to the tune of 0.2 to 1.3 cm/yr respectively

Ground water in the district is mostly developed through dug wells and bore wells. About 90% of the rural and 60% of the urban drinking water supply schemes in the district depends on ground water.

ACKNOWLEDGEMENT

The author is grateful to Shri Sunil Kumar, Chairman, Central Ground Water Board for giving opportunity for preparation of the National Aquifer Mapping & Management report of Raipur district, Chhattisgarh. I express my sincere gratitude to Shri Sateesh Kumar, Member (East), CGWB for giving valuable guidance, encouragement and suggestions during the preparation of this report.

The author is thankful to Dr. Prabir K. Naik, Regional Director, Central Ground Water Board, NCCR, Raipur for extending valuable guidance and constant encouragement during the preparation of this report. I am grateful to Sh. A.K. Biswal, Scientist-E for his continuous guidance and support during preparation of this report. The author is also thankful to Dr. P. K Naik, Regional Director (Retd.) and Sh A.K. Patre, Sc-D for the guidance and suggestions. The author is also thankful to Sh Rakesh Dewangan, Sc-B and Ms. Anita Bind, STA (Chemical) for the chemical analysis and valuable inputs on quality issues. The author is also thankful to Sh A. K. Sinha, Sc-B for sharing the geophysical studies. The efforts made by Sh. T.S. Chouhan, Draftsman, for digitization of maps are thankfully acknowledged. The author is also thankful to the state agencies for providing the various needful data. The author is thankful to Technical Section, Data Centre, Chemical Section, Report Processing Section and Library of CGWB, NCCR, Raipur for providing the various needful data.

Priyanka B. Sonbarse

Scientist-B

DISTRICT AT A GLANCE: RAIPUR DISTRICT

1.	**GENERAL INFORMATION**	
	i) Geographical area (Sq. km)	2892
	ii) Administrative Divisions (As on 2020)	
	a) Number of Blocks	4
	b) Number of Villages	485
	iii) Population as on 2017	2160876
	iv) Average Annual Rainfall	1240 mm
2.	**GEOMORPHOLOGY**	
	i) Major Geomorphological Units	Dissected pediplain made by Proterozoic shale-limestone dolomite area
	ii) Major Drainages	Mahanadi Basin (Mahanadi, Pairy, Sondur, Kharun and Shivnath)
3.	**LAND USE (ha) As on 17-18**	
	i) Forest Area	1671
	ii) Net Area Sown	161299
	iii) Double cropped Area	34066
4.	**MAJOR SOIL TYPES**	Vertisol -Red sandy gravelly & Red sandy, Ultisols- Red & Yellow, lateritic
5.	**AREA UNDER PRINCIPAL CROPS, in ha (As on 2017-18)**	Paddy-162416, Wheat-4316, Pulses-20632, Tilhans-273, Fruits and vegetables- 307
6.	**IRRIGATED AREA BY DIFFERENT SOURCES in ha (As on 2017-18)**	
	i) Dug wells	302
	ii) Tube wells/Bore wells	33885
	iii) Canals	105561
	iv)Tanks	2239
	v) Other sources	2181
	vi) area Irrigated more than once	9946
7.	**NUMBERS OF GROUND WATER MONITORING WELLS OF CGWB (As on March'2020)**	
	i) No of Dug wells	41
	ii) No of Piezometers	18

8. PREDOMINANT GEOLOGICAL FORMATIONS

Recent Alluvium & Laterite (Sand, clay)
Raipur Formation (Limestone, Dolomite, Sandstone, shale)

9. HYDROGEOLOGY

i) Major Water Bearing Formations	Weathered & fractured shale, limestone
ii) Pre-monsoon Depth to Water Level	1.9 to 18.54 mbgl
iii) Post-monsoon Depth to Water Level	0.77 to 10 mbgl
iv) Long Term Water Level Trend for 10 yrs (2009-2019)	**Pre-monsoon-** Rise : 0.6 to 5.4 cm/yr **Post-monsoon-** Fall: 0.1 to 4.5 cm/year Rise 0.2 to 1.3 cm/yr

10. GROUND WATER EXPLORATION BY CGWB (As on March'2021)

i) No of Wells Drilled	EW: 60, OW: 13, PZ: 14
ii) Depth Range (m)	32 to 304
iii) Discharge (litres per second)	0.2 to 13
iv) Transmissivity (m^2/day)	2 to 121.7

11. GROUND WATER QUALITY

i) Presence of Chemical Constituents	EC for Shallow aquifer is 108 to 2345 and for deeper aquifer is 91 to 1541 µS/cm at 25°C , PH- 7 to 8.9, All the chemical constituents are well within permissible limit except Nitrate at few places.
ii) Type of Water	Calcium-Bicarbonate (Ca-HCO_3) type for shallow aquifer & Na-K-Bicarbonate type (Na,K-HCO_3) type for deeper aquifer respectively.

12. DYNAMIC GROUND WATER RESOURCES in Ham (Estimated as on March'2013)

i) Annual Extractable Ground Water Recharge	42499.6
ii) Total Annual Ground Water Extraction	28840.83
iii) Ground Water Resources for Future use	13585.14
iv) Stage of Ground Water Development	68.23 %

13. AWARENESS AND TRAINING ACTIVITY

Mass Awareness Programmes Organized

i) Year 1998-99, Place: Raipur
ii) Year 2000-01, Place:Raipur
iii) Year 2003-04, Place: Raipur
iv) Year 2004-05, Place: Raipur
v) Year 2005-06, Place: Raipur
vi) Year 1999-2000, Place:Dharsiwa
vii) Year 2020-21, Place: Arang

Water Management Training Programmes Organized

i) Year 1998-99, Place: Raipur
ii) Year 2000-01, Place: Raipur
iii) Year 2003-04, Place: Raipur
iv) Year 2010-11, Place: Raipur
v) Year 2014-15, Place: Raipur
vi) Year 2017-18, Place: Raipur

14. EFFORTS OF ARTIFICIAL RECHARGE & RAINWATER HARVESTING

i) Projects Completed by CGWB (No & Amount spent)	Nil
ii) Projects Under Technical Guidance of CGWB (Numbers)	Nil

15. GROUND WATER CONTROL AND REGULATION

i) Number of Over Exploited Blocks (Stage of Extraction > 100%)	Nil
ii) Number of Critical Blocks (Stage of Extraction> 90%)	1
iii) Number of Blocks Notified	Nil

16. MAJOR GROUND WATER PROBLEMS AND ISSUES

High stage of groundwater development, inherent character of aquifer giving low yield, growing water consuming crops in spite of critical stage of development and declining of water level are the major ground water issues in the district.

CONTENTS

ABBREVIATIONS

a msl	above mean sea level
BDR	Basic Data Report
CGWB	Central Ground Water Board
Dia	Diameter
DTW	Depth To Water
EC	Electrical Conductivity
EW	Exploratory Wells
GW/ gw	Ground Water
ham	Hectare meter
lpcd	litres per capita per day
lpm	litres per minute
lps	liters per second
m bgl	meter below ground level
MCM/mcm	Million Cubic Meter
NCCR	North Central Chhattisgarh Region
NHNS/ NHS	National Hydrograph Network Stations
OW	Observation Well
PZ	Piezometre

INTRODUCTION

1.1 Objectives

The groundwater is the most valuable resource for the country. The demand for ground water for various types of use is increasing day by day; consequently indiscriminate development of ground water has taken place and the ground water resource has come under stress in several parts of the country. On the other hand, there are also areas where adequate development of ground water resources has not taken place. These facts underscore the need for micro-level study of the aquifer systems of the country. Central Ground Water Board (CGWB) is involved in hydrogeological investigations covering major part of the country and as per requirement; the reappraisal of ground water regime is being taken up in priority areas to generate the background data on regional scale. CGWB has also carried out ground water exploration in different phases with prime objective of demarcating and identifying the potential aquifers in different terrains for evaluating the aquifer parameters and for developing them in future. The reports and maps generated from the studies are mostly based on administrative units such as districts and blocks and depict the subsurface disposition of aquifer on regional scale. However, due to paradigm shift in focus from development to management of ground water in last one decade, the need for more reliable and comprehensive aquifer maps on larger scale has been felt for equitable and sustainable management of the ground water resources at local scale. Volumetric assessment of ground water and strategies for future development and management are the primary objective of aquifer mapping.

1.2 Scope of the study

The aquifer maps are the maps depicting aquifer disposition, giving lateral and vertical extension. The maps will also provide information on the quantity and quality. Aquifer mapping is a multidisciplinary scientific process wherein a combination of geological, hydrogeological, geophysical, hydrological and quality data is integrated to characterize the quantity, quality and movement of ground water in aquifers.

It explains the components of the Aquifer Classification System, outlines the assumptions underlying the map information presented and also summarizes the content of an aquifer classification map. The goal is to help the map users understand the strengths and limitations of the information contained on the aquifer classification maps so that they can apply that information appropriately to their particular water and land management needs. The system and maps are designed to be used together and in conjunction with other available information as a screening tool for setting groundwater management priorities. They provide a way of comparing aquifers within a consistent hydrogeological context and prioritizing future actions at various planning levels. The maps may provide some background information for site-specific projects. However, the maps are not to be used for making site-specific decisions. The classification of an aquifer reflects the aquifer as a whole and at a specific time. Groundwater conditions, such as the degree of vulnerability and water quality, can vary locally and over time respectively. This variability in the data sometimes requires subjective decision-making and generalising of information for an entire aquifer.As such the following four blocks were studied under NAQUIM program in 2019-20 as following table 1.1.

Table-1.1: Details of area covered under NAQUIM in Raipurdist

Sl. No.	District	Block	Geographical Area (sq.km)
1	Raipur	Abhanpur	604
2		Arang	900
3		Dharsiwa	652
4		Tilda	735
Raipur district		Total	2892

Source: AAP:2020-21

1.3 Methodology

The activities under the aquifer project can be summarized as follows:

i) Data Compilation & Data Gap Analysis: One of the important aspect of the aquifer mapping programme was the synthesis of the large volume of data already collected during specific studies carried out by the Central Ground Water Board and various other government organizations with a new set of data generated that broadly describe an aquifer system.The data were compiled, analysed, synthesized and interpreted from available sources. These sources were predominantly non-computerised data that were converted into computer based GIS data sets. On the basis of these available data, Data Gaps were identified.

ii) Data Generation: It was evident from the data gap that additional data should be generated to fill the data gaps in order to achieve the objective of the aquifer mapping programme. This was done by multiple activities like exploratory drilling, hydro-chemical analysis, use of geophysical techniques as well as detail hydrogeological surveys. About 80 nos. of exploratory wells, observation wells and piezometers drilled by CGWB in various periods in different formation,35nos of key observation wells (dug wells, hand pumps and piezometers) established during the survey and 28nos of ground water samples from different sources representing shallow as well as deeper aquifers were studied carefully and analysed before preparing the aquifer map and management plan.

iii) Aquifer map Preparation: Based on integration of data generated through various hydrogeological and geophysical studies, aquifers have been delineated and characterized in terms of quality and potential. Various maps have been prepared bringing out the Characterization of Aquifers. These maps may be termed as Aqifer Maps depicting spatial (lateral and vertical) variation of the aquifers existing within the study area, quality, water level and vulnerability (quality and quantity).

iv) <u>Aquifer Management Plan</u>: Based on the integration of these generated, compiled, analysedandinterpreted data, the management plan has been prepared for sustainable development of the aquifer existing in the area.

1.4Location, Administrative set up &Demography

Raipur is the capital city of the Indian state of Chhattisgarh. Raipur is also the administrative headquarters of Raipur district and Raipur division, and the largest city of the state. It was a part of Madhya Pradesh before the state of Chhattisgarh was formed on 1 November 2000. It has exponential industrial growth, and has become a major business hub in central India. Raipur district is an important industrial and mining district of the Chhattisgarh State which is known for its Agriculture and Irrigation on synchronized and systematized pattern from the past as the garner of popularity for its productivity in paddy crops in whole of Chhattisgarh belt. It is distinguished for its being the center of Education and Research not only in the academic field of humanities, science and agriculture, medicine and mediation but also in the field of ground water and irrigation in the vast region of Chhattisgarh State. Raipur district is situated in the central part of the Chhattisgarh.

It is bounded in the north by Baloda bazar district, in the west byBemetara andDurg district in a continuous pattern of land and people. Gariaband and Mahasamund district of Chhattisgarh state defines the eastern boundary of the Raipur district, where as its south boundary is delimited by the district Dhamtari of Chhattisgarh state.

A network of all weather motorable roads connects all the enclaves of the district. The district head quarter of Raipur lies on the Bombay- Howrah, southeastern central railway line. Apart from Railway lines, National Highways also provide effective communication and conveyance of conveniences for trade, travel and commerce in the district.

It is situated between north latitudes of 20°56’56’’ to 21°37’30’’ and east longitudes 81°32’13’’ to 82°11’50’’ falling within survey of India Degree sheets No. 64G, H, K, L and 65I. and is divided into 4 tehsils and 4 blocks, comprising 4 Urban Centers and 485villages (Table-1.2&Map-1.1).Geographically it covers an area of 2892 Sq Km. According to 2011 census record the total population of district is 2160876.The decadal growth of population is 34.64%. The high decadal growth in population is attributed to the growth in population in urban areas which includes the capital city of Raipur as well.

Mahanadi is the principal river of this district. Its tributaries are Pairy, Sondur, Joan, Kharun and Shivnath. The fertility of lands of Raipur district can be attributed to the presence of these rivers. Mahanadi originating in the hills of Sihava flows in the direction of East into the Bay of Bengal. Mahanadi crosses the district diagonally from its south western corner to Northern boundaries.

Table-1.2: Administrative details of Raipur district (As per 2017)

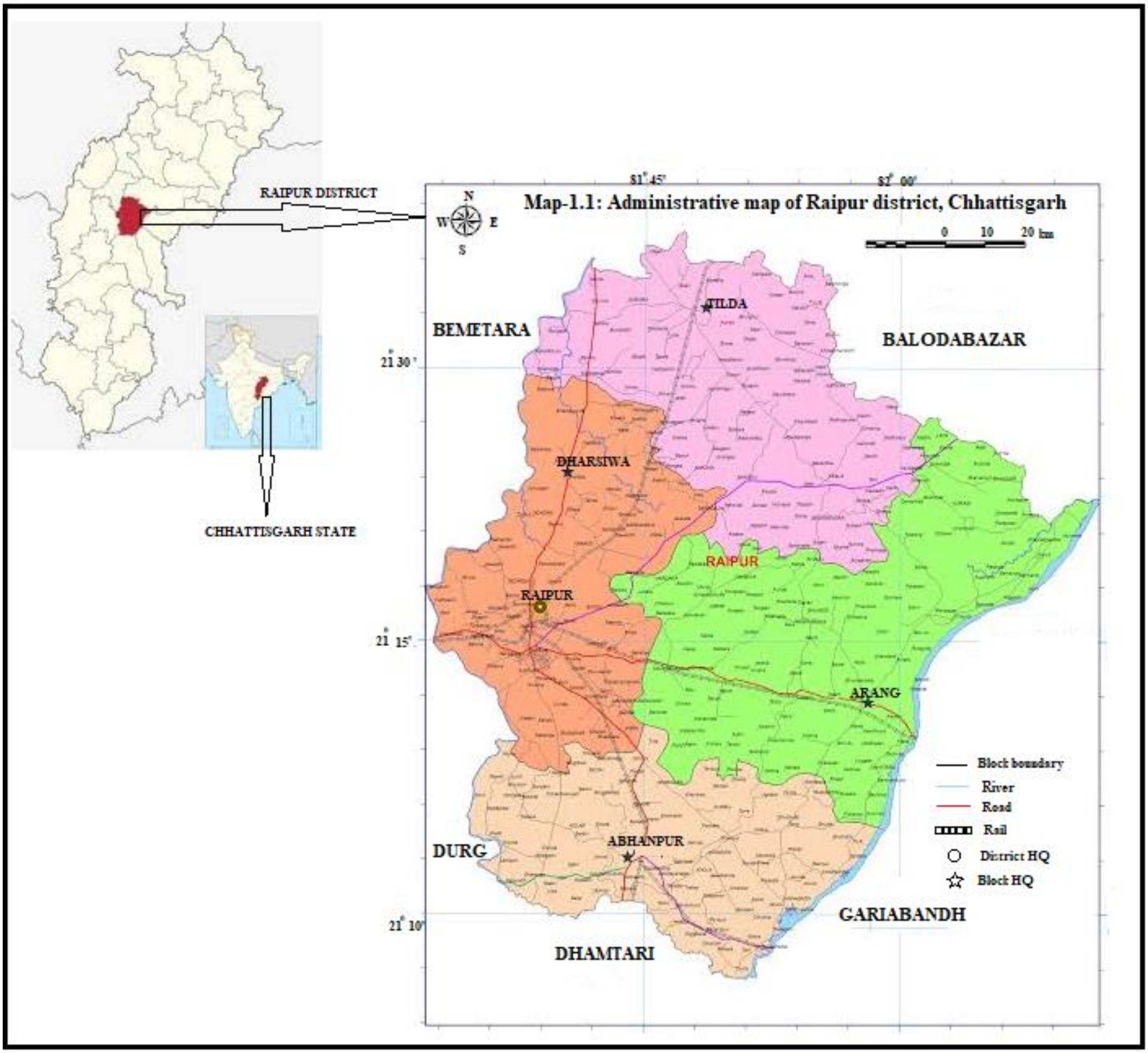
Sl. no	Tehsil	Block	Number of				
			Population	Towns	Nagar Panchyat / Nagar Nigam	Village pancahyat	Villages
1	Dharsiwa	Dharsiwa	1366141	1	2	78	83
2	Arang	Arang	314489	1	0	140	166
3	Tilda	Tilda	238157	1	1	99	132
4	Abhanpur	Abhanpur	242089	1	1	91	104
Total			***2160876***	***4***	***4***	***408***	***485***

Source: District Statistical Book-2017

1.5 Land use

The total geographical area of the district is 2892sq.km. Only 0.57 % of the total area is covered by forests. Agricultural land covers 149.8sq.km. Waste/Barren land covers 62.56sq.km. Area under nonagricultural use is 470.24 sq.km. The net sown area during the year 2017-18 is 359.94 sq.km. Area sown more than once i.e double cropped area is 58.5 sq. km while the gross cropped area accounts 418.44 sq. km. The land use/land cover map of Raipurdistrict is presented in Map-1.2 and detail land use pattern for the district is shown in table 1.3.

Map-1.1: Administrative map of Raipur district, Chhattisgarh



Map-1.2: Landuse map of Raipur district, Chhattisgarh

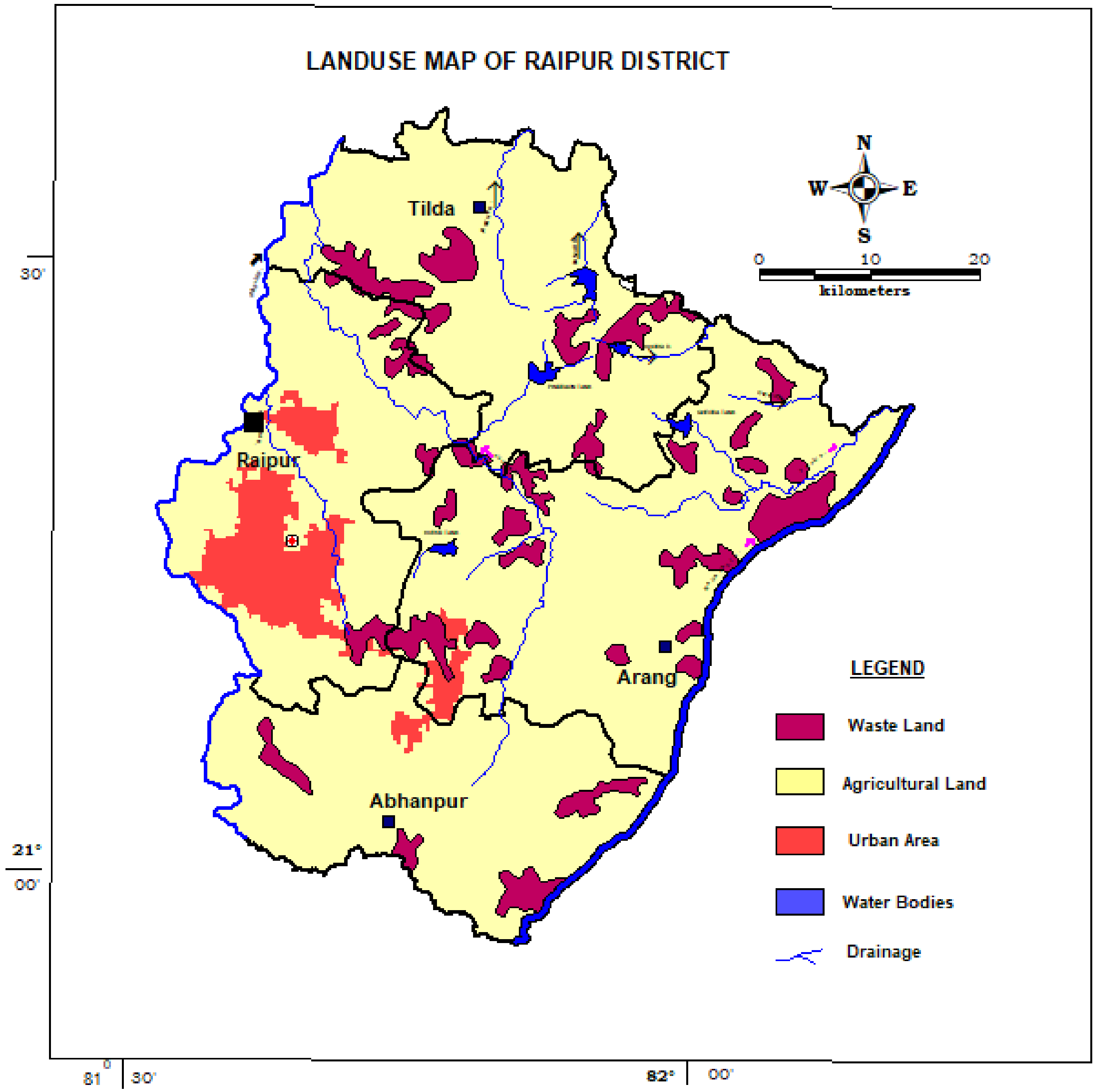


Table-1.3: Land use pattern in Raipur district during the year 2017-18 (in ha)

Sl. No	Blocks	Total geographical Area	Revenue forest area	Area not available for cultivation	Non agricultural& Fallow land	Agricultural Land	Agricultural Fallow land	Single cropped areaarea	Double cropped area	Gross cropped area
1	Dharsiwa	65232	0	20086	13468	6490	1460	23727	7087	30814
2	Arang	90039	448	10966	16610	2697	1625	57693	15137	72830
3	Tilda	73531	832	8367	15699	2951	1796	43885	5992	49877
4	Abhanpur	60398	391	7605	12191	2842	1375	35994	5850	41844
Total		***289200***	***1671***	***47024***	***57968***	***14980***	***6256***	***161299***	***34066***	***195365***

Source: District Statistical Book-2017

1.6 Cropping pattern

Kharif is the main cropping season in Raipur district and Paddy is the main crop followed by wheatandmaize. The pulses, tilhan, fruits, vegetables, mirch masala and sugarcane etc. are also grown in the district. Rice is sown in nearly 83% of the gross cropped area. The cropping pattern in the district is shown in table 1.4. Mainly paddy and cereals are cultivated both in kharif and rabi season.Theseason wise cropping details are presented in table-1.5 A & B.

Table-1.4: Cropping pattern in Raipur district during the year 2017-18 (in ha)

Sl. No	Blocks	Kharif	Rabi	Cereal				Pulses	Tilhan	Fruits / Vege tables	Mirch Masala	Sugar-cane
				Rice	Wheat	Jowar & Maize	Others					
1	Dharsiwa	24015	6799	23486	1171	110	0	4160	29	67	97	29
2	Arang	57149	15681	59493	954	70	0	10561	48	119	96	20
3	Tilda	43715	6162	43094	1664	130	0	2682	183	37	145	98
4	Abhanpur	35892	5952	36343	527	92	0	3229	13	84	91	21
	Total	***160771***	***34594***	***162416***	***4316***	***402***	***0***	***20632***	***273***	***307***	***429***	***168***

Source: District Statistical Book-2017

Table 1.5 A: Season wise cropping pattern

Rainfed	**Irrigated**
Rice, Wheat, Soyabean, Arharkodo, Moong, Til, Maize, Mustard	Rice, Sunflower, Maize, Vegetable, Sugarcane

Source: Commissioner Land record-2017

Table 1.5 B: Season wise cropping area (in ha)

Block	**Season**	
	Kharif	**Rabi**
Dharsiwa	24015	6799
Arang	57149	15681
Tilda	43715	6162
Abhanpur	35892	5952
Grand Total	***160771***	***34594***

Source: Commissioner Land record-2017

Table 1.5 C: Season wise cropping area (in ha)

Crops	Season	
	Kharif	**Rabi**
Paddy	156860	22090
Wheat	0	2950
Sugarcane	0	180
Maize	400	280
Total Cerals	157260	25320
Total Pulses	600	23290
Total Oil seeds	430	1190
Total Vegetables	2480	2880
Grand Total	***160770***	***34660***

Source: Commissioner Land record-2017

1.7 Irrigation

The district is benefitted by one major irrigation project namely- (i) Mahanadi Main Canal of Mahanadi Project Group which is completed projects which have an ultimate potential of 1171.22 lakh hectares being highest in Arang block (453.1 lakh ha). The details of projects is given in Table 1.7 A.

Major Project		
		Irrigation Potential in ,000 ha
Mahanadi Main Canal of Mahanadi Project	Dharsiwa	19077
	Arang	45310
	Tilda	20935
	Avanpur	31800
Total Irrigation Project		*117122*
Medium Project		
Kumhari Reservoir	Tilda	2632
Pindavar Reservoir	Tilda	2592
Total Irrigation Project		*5224*

Source: WRD deptt.-2017

The net irrigated area during the year 2017-18 is 134222 hectares. The percentage of the irrigated area to net sown area in Raipur district is 73.79%. Irrigation by ground water covers 25.47 % of the net irrigated area. The area irrigated by various sources is presented in table-1.6 and is also shown in **Fig-1(A&B)**.

Table-1.6: Area irrigated by various sources in Raipur district during the year2017-18 (in ha)

SNo	Blocks	Canal (private and Govt.)		Bore wells/ Tube wells		Dug wells		Talabs		Irrigated area by other sources	Irrigated area by GW sources	Net Irri-gated area	Irrigated area more than once	Gross irrigated area	% of Net irrigated area to. Net area sown
		Nos	Irrigated area (ha)	Nos	Irrigated area	Nos	Irrigated area	Nos	Irrigated area						
1	Dharsiwa	1	11965	3239	8288	131	51	45	551	1466	8339	19545	2776	22321	72.44
2	Arang	6	46220	4036	8160	1081	126	105	503	565	8286	52991	2583	55574	76.31
3	Tilda	6	17135	3252	11518	614	53	142	837	110	11571	26649	3004	29653	59.45
4	Abhanpur	4	30241	2823	5919	651	72	27	348	40	5991	35037	1583	36620	87.52
	Total	***17***	***105561***	***13350***	***33885***	***2477***	***302***	***319***	***2239***	***2181***	***34187***	***134222***	***9946***	***144168***	***73.79***

Source: District Statistical Book-2017

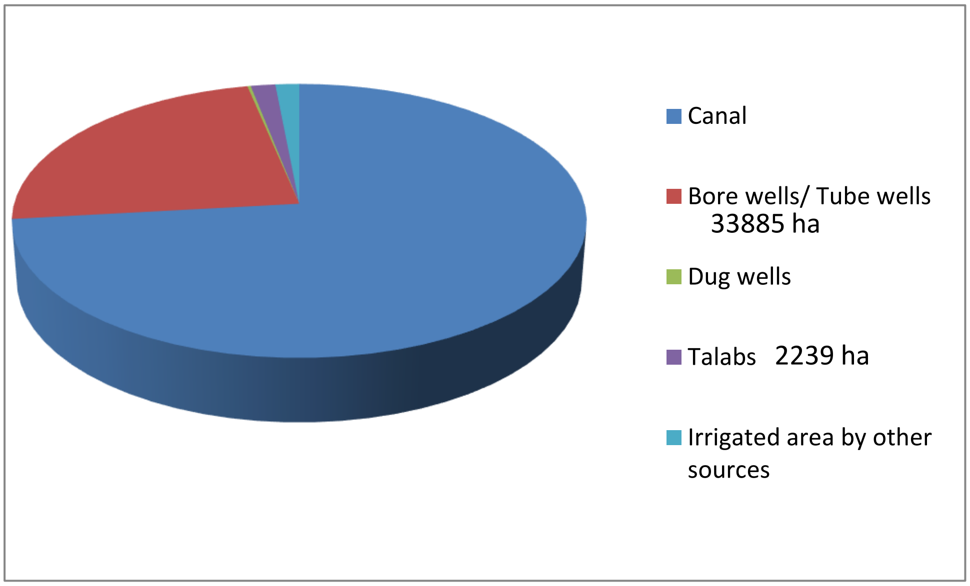


Fig.1-A: Area irrigated in ha by different sources in Raipur district, Chhattisgarh

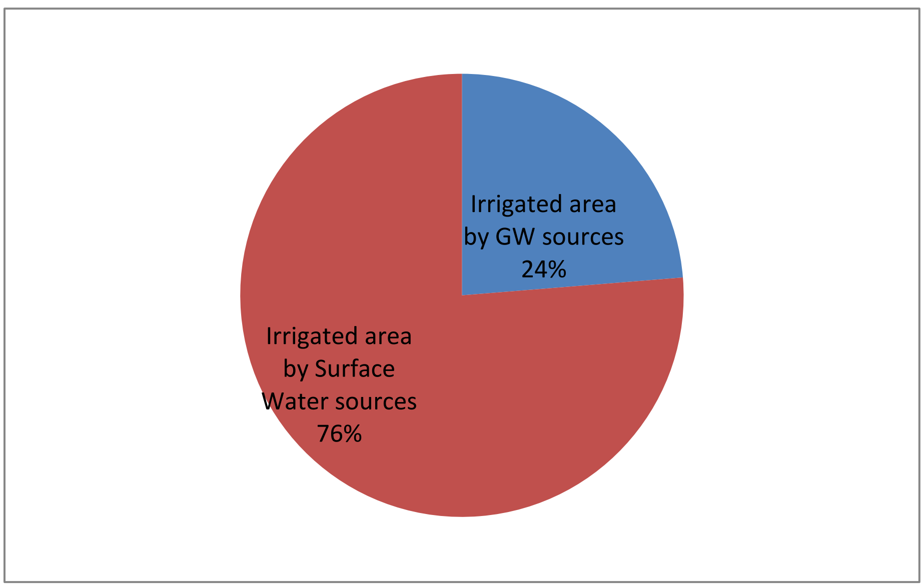


Fig.1-B: Area irrigated in percentage by GW and Surface water sources in Raipur district, Chhattisgarh

1.8 Minerals, Industries and Mining activities

Chhattisgarh is the hub of power and steel plants. Rice mills are Trans growing in few districts of the State. Household industry plays an important role in the economy of the state. A large number of Steel making industries, Rolling mills, Sponge iron plants, Cement factories, Welding consumables, Industrial electronic products, Power and Process control equipment are the major industries in the district.Raipur district is famous for its various grades of Limestone deposit viz high grade, (cement grade) blendable/Beneficial grade, Low grade etc. Minor mineral (Low grade limestone) Dolomite, Laterite, Sandstone, River sand are also found in huge quantity in Tilda, Kesla, Mohrenga, Kathiya, Patharakundi, number of Mining Lease have been sanctioned for cement grade limestone. CCI Mandhar (abondoned), Century cement (Baikunth), Gangotri Limes (Dondekala), ORS Minerals (Matiya) are main limestone based industry in the district. 137 Nos. of Quarry leases for limestone have sanctioned for road and building material, 16 otherof clay and flag stone for making bricks and tiles locally. The major limestone belts of the district are:- (1) Bangoli - Kharora - Mohrenga (2) Murra-Dhansuli (3) Pirda-Bahnakadhi (4) Dondekala-Dondekhurd-Lalpur-Matiya (5) Madhi-Khapri-Sontara. Overall mining activity in the district are running in fullswing in term of limestone as minor mineral (building and road material), 46 Leases sand mining in bank of Mahanadi river at different villages and material like murrum ordinary stones are also permitted for quarrying of material at number of places.

1.9 Soils

As per the US soil taxonomy only two soil types namely Vertisol and Ultisol have been found in the district. The distribution of different soil types in Raipur district is presented in **Map-1.3.**The soil orders in US soil taxonomy and their Indian equivalents, which are found in the district, are:

Table-1.8 (A): Soil Classification (Type wise)

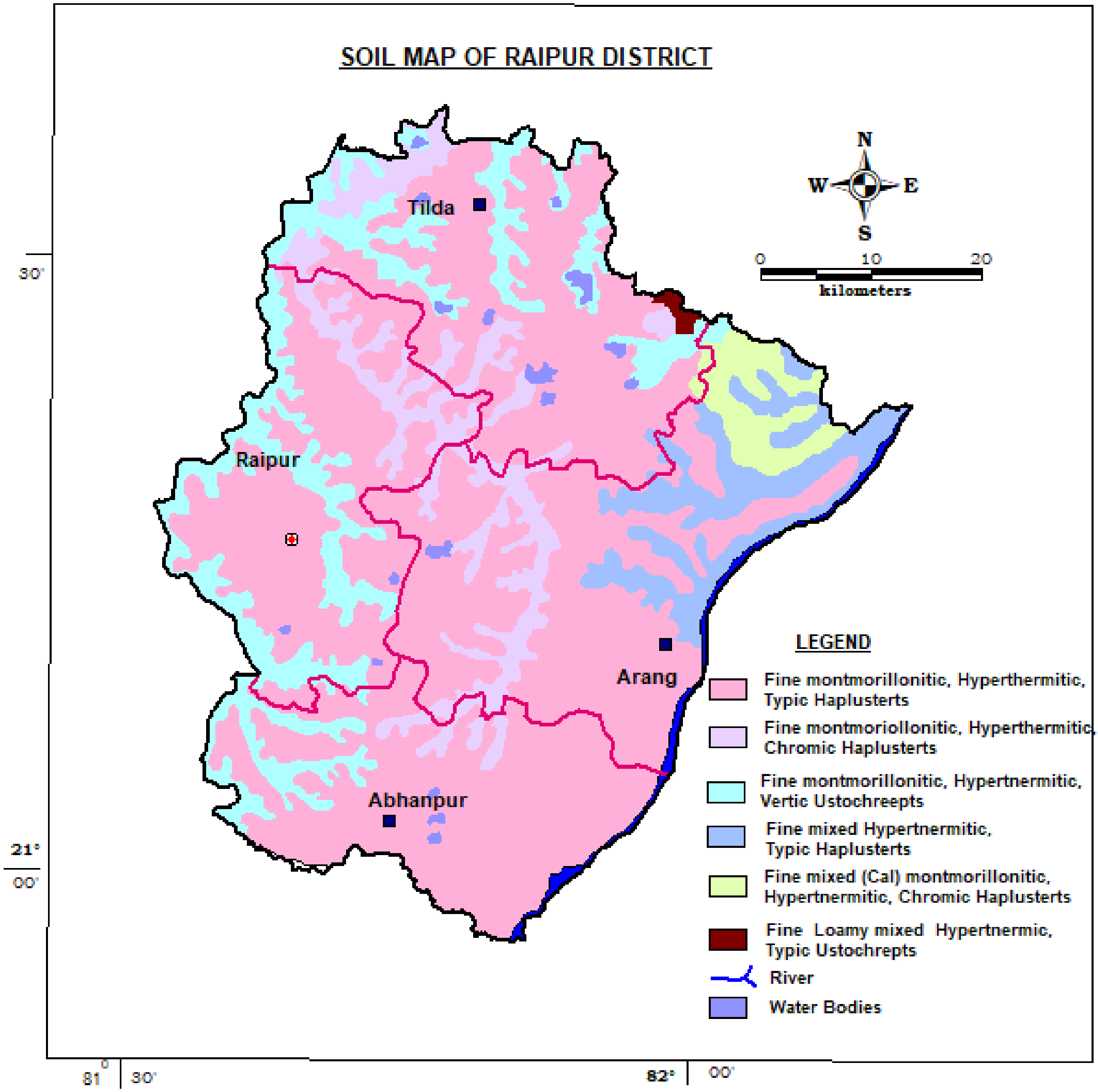
Sl. No.	US soil taxonomy	Indian equivalents
1	Vertisol	Deep black soil
		Medium black soil
2	Ultisol	Lateritic soil
		Red and yellow soil

Vertisols

They are characterized by a high content of expanding and shrinking clay known as montmorillonite that forms deep cracks in certain seasons.The Indian equivalents of Vertisols which are available in the district are deep and medium black soils. These soils cover maximum parts of the district and are distributed in the entire district except the central and eastern part.

UltisolsThe word "Ultisol" is derived from "ultimate", because Ultisols were seen as the ultimate product of continuous weathering of minerals in a humid temperate climate. This is a highly weathered and leached acid soil with high levels of clay below the top layer. They are characterized by a humus-rich surface horizon (the uppermost layer) and by a layer of clay that has migrated below the surface horizon.The Indian equivalent of Ultisols which are available in the district are Lateritic soil and red & yellow soils. They mainly occupy the entire eastern part and also as patches in the southern and central part of the district.

Map-1.3: Soil map of Raipur district, Chhattisgarh



1.10 Drainage

The drainage system of the district (**Map-1.5**)constitutes the river Mahanadi which is the principal river of this district. Its tributaries are Pairy, Sondur, Kharun and Shivnath. The fertility of lands of Raipur district can be attributed to the presence of these rivers. Mahanadi originating in the hills of Sihava flows in the direction of East into the Bay of Bengal. Mahanadi crosses the district diagonally from its south western corner to Northern boundaries.The drainage system in the plain as well as hilly areas is open dendritic consequent type.

Kharun

Kharun river flows in eastern parts of the district starting from Petechua in Balod District. This river flows towards north and joins (meet) Shivnath River at Somnath near Simga. This river determines the boundary of Raipur and Durg district. The length of this river is about 120 km.

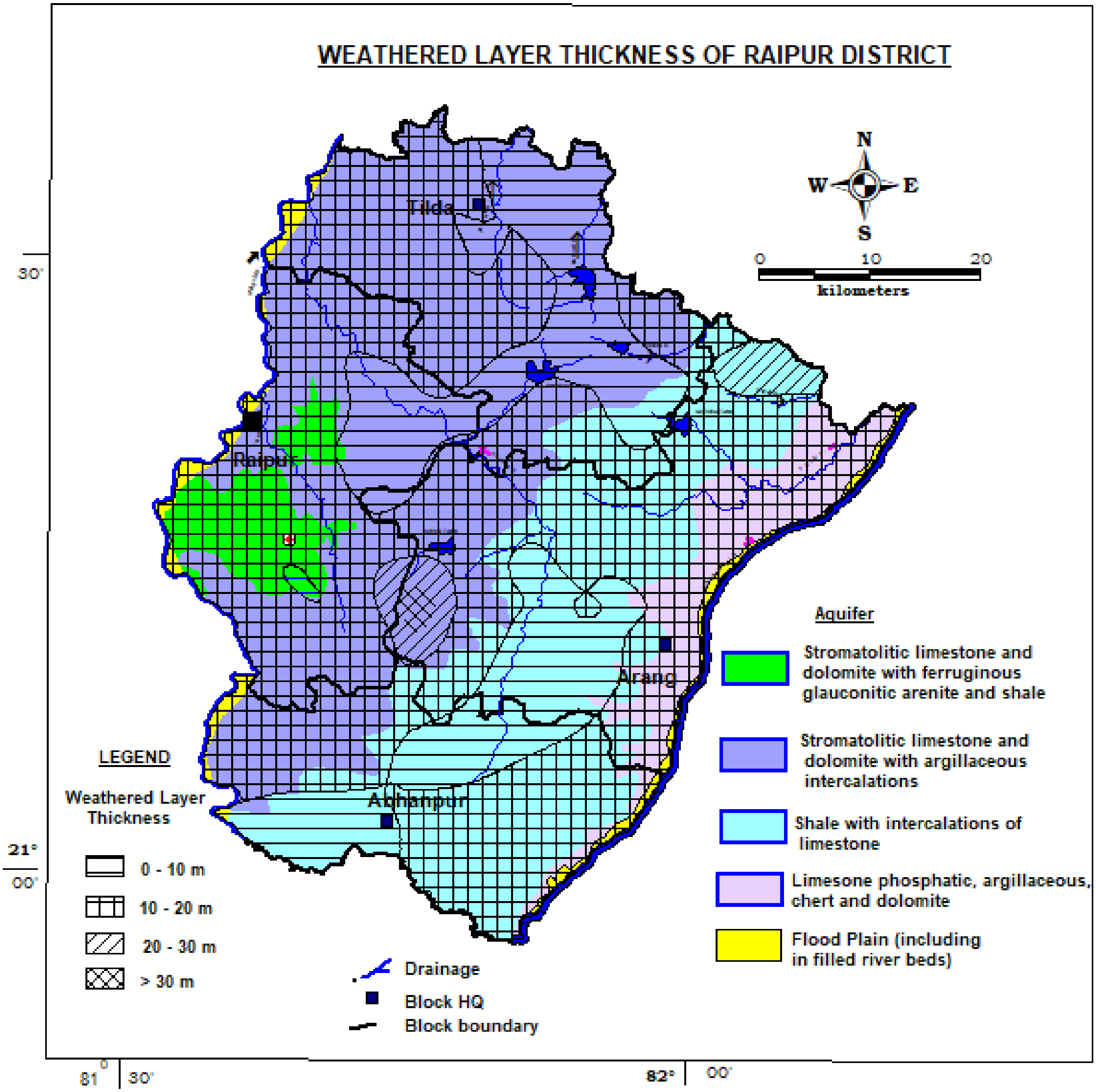
Mahanadi

The Mahanadi is a major river in East Central India. It drains an area of around 141,600 square kilometres (54,700 sq mi) and has a total course of 858 kilometres (533 mi. The river flows through the states of Chhattisgarh and Odisha.The word Mahanadi literally comes from two odia words 'maha' and nadi' meaning 'The Great River'. Like many other seasonal Indian rivers, the Mahanadi too is a combination of many mountain streams and thus its precise source is impossible to pinpoint. However its farthestheadwaters lie 6 kilometres (3.7 mi) from Pharsiya village 442 metres (1,450 ft) above sea level south of Nagri town in Dhamtari district of Chhattisgarh. The hills here are an extension of the Eastern Ghats and are a source of many other streams which then go on to join the Mahanadi. For the first 80 kilometres (50 mi) of its course, the Mahanadi flows in a northerly direction and drains the Raipur district and touches eastern portions of Raipur city. It is a rather narrow river at this stage and the total width of its valley does not exceed 500–600 metres. Sand is mined from the bank of Mahanadi, Sheonath and Kharun , but most of the Retghat is running in Mahanadi river of Arang and Abhanpur Tehsil. The valley between the Mahanadi and the Kharun is marked by a long ridge of higher land extending from Kurud in the south, through Abhanpur, Lakholi, Kharora and Palari to Lahud in the north east direction. The low ridge bifurcates near Abhanpur and its western branch extends through Mandir Hasaud to Mandhar in the north. The Mahanadi main canal and its branches and distributaries have been constructed along these ridges or their off-shoots. A large number of small streams flow through the low-lying areas which are diverted to join the Mahanadi in the east, the Kharun in the west and the Seonath in the north.

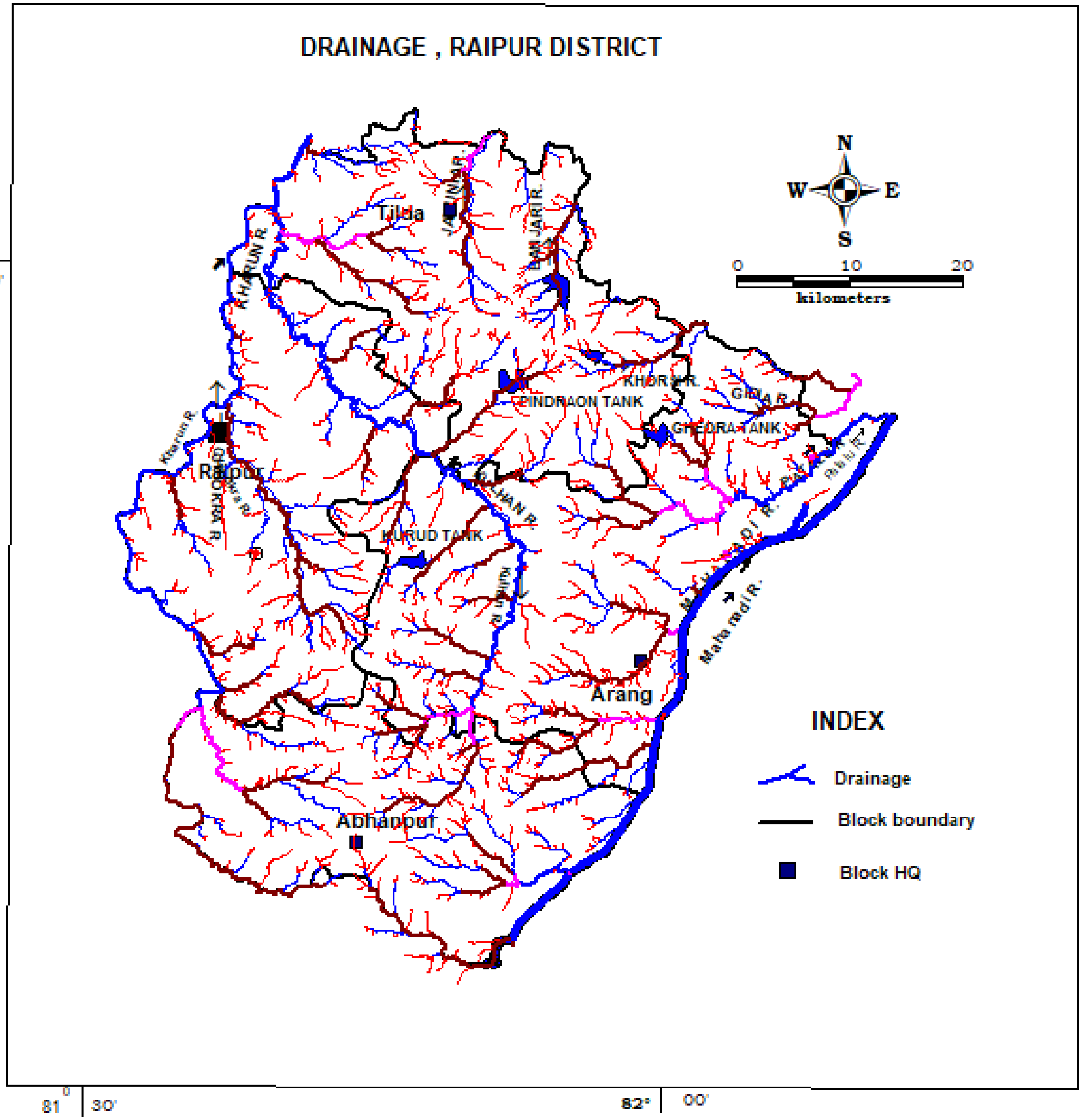
Seonath

River Seonath flows on 7.50 km length in Raipur district along the interiors of Tilda block at the district border of Raipur - Bemetara where no major demand of sand observed. Therefore river Seonath is also not being used as source of sand in the district Raipur.

Map-1.4: Weathered Layer map (depth wise) of Raipur district, Chhattisgarh



Map-1.5: Drainage map (major) of Raipur district, Chhattisgarh



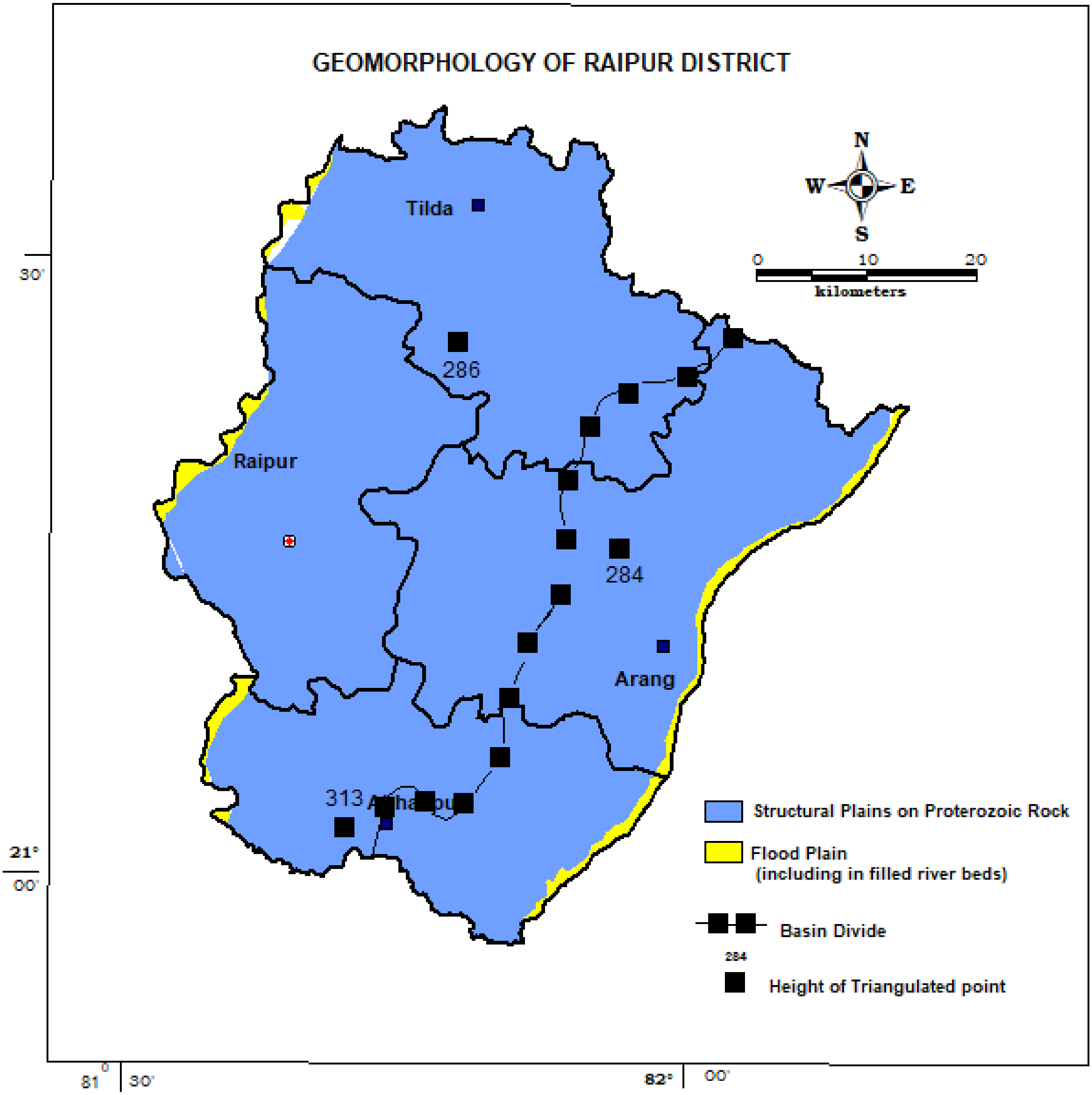
1.11Geomorphology

Raipur district characterized by rocks belonging to Proterozoic age and the main rocks is Limestone and dolomite and then Laterite and soil are found ranging age between sub-recent to recent. Physiographically the area in Raipur district having plains belonging to Chhattisgarh basinal area with an elevation of 278 feet(298.16 meters) above m.s.i. and the general slop is towards the north-east. Geomorphologically the district is having matured type of land forms and can be broadly divided into two prominent geomorphic units. These are 1. Dissected pediplain made by Proterozoic shale- limestone dolomite area. 2. Alluvial Plain formed by Seonath-Mahanadi Alluvium. The geomorphological map of Raigarh district is presented in **Map-1.6.**

1.12 Prevailing Water Conservation and recharge practices

There are 319nos of ponds which are used for irrigation of 2239 ha. Besides there are nos of small ponds exist in the district which are mainly used for various domestic purposes and artificial recharge. Under MGNREGA , till date 368nos of water conservation and water harvesting structures have been completed . 1281nosstructures are ongoing for water conservation and harvesting.However these ponds need to be renovated for the optimum ground water recharge. There are some check dams and nalla bunds prevailed in the district which is constructed for ground water recharge purposes.

Map-1.6: Geomorphological map of Raipur district, Chhattisgarh



HYDROMETEROLOGY

2.1 Introduction

TheRaipurdistrict experiences sub-tropical climate and is characterized by extreme summer and winter seasons. The summer months are from March to May and the months of April and May are the hottest. The rainy season extends from the month of June to September with well distributed rainfall through southwest monsoon. Monsoon generally breaks in the third week of June and is maximum in the months of July and August. Winter season is marked by dry and cold weather with intermittent showers during the months of December and January.

2.2 Temperature

Raipur has a tropical wet and dry climate, temperatures remain moderate throughout the year, except from March to June, which can be extremely hot. The temperature in April–May sometimes rises above 48 °C (118 °F).These summer months also have dry and hot winds. In summers, the temperature can also go up to 50 °C. The city receives about 1,300 millimetres (51 in) of rain, mostly in the monsoon season from late June to early October. Winters last from November to January and are mild, although lows can fall to 5 °C (41 °F).

2.3 Evaporation

The evaporation variations are almost sympathetic with the variations of temperature. The evaporation is maximum in the month of May and minimum during the months of December and January.

2.4 Humidity

The atmospheric humidity is usually low during summer months around 25%. However humidity slowly starts building up from third week of May and it reaches maximum around 85% during monsoon period. The humidity again decreases in winter season and it varies between 30 to 40% during winter season.

2.5 Wind Velocity

The wind flows easterly or westerly during the southwest monsoon period. During post-monsoon and winter seasons the wind directions are between north and east and sometimes westerly. The wind speed of more than 10 km/hr is recorded during the monsoon months (from June to September). In the post-monsoon and winter months (from October to February), the wind speed is less than 5 km/hr and in the summer months (March to May) the wind speed is more than 7 km/hr.

2.6 Rainfall

The Raipur district receives rainfall mainly from south-west monsoon. It sets in third/fourth week of June and continues till mid August/September with heaviest showers in the months of July and August. The average annual rainfall for Raipur district is around 1239.81 mm (2012 to 2017).

Table2.1 is presented below to show annual rainfall in Raipur district for the period of six years from 2012 to 2018. The months of July and August are the heaviest rainfall months and nearly 95% of the annual rainfall is received during June to September months.

Table-2.1: Annual Rainfall (mm) in Raipur district for the years (2012-2018)

Block	**Rainfall in mm**						**Average Annual rainfall (2012-18) (mm)**
	2012-13	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	
Dharsiwa	1716.7	1599	1182.5	1041.3	1359	870.6	1294.85
Arang	1924	1959	1134.6	751.8	872.2	899.7	1256.883
Tilda	1669.3	1702.03	1299.5	1102.6	1229	622.8	1270.872
Abhanpur	1509	1539	1167.9	625	1193	786	1136.65
Average Annual Rainfall of Raipur district	***1704.75***	***1699.7575***	***1196.125***	***880.175***	***1163.3***	***794.775***	***1239.81***

Source: Statistical Handbook,2018

GEOLOGY

3.1 Geology and structure

The district is mainly covered by rocks of Meso to Neo Proterozoic age, with some isolated pockets of Recent to Sub-recent alluviumcomprising crystalline and metamorphic and consolidated sedimentary rocks of Chhattisgarh Super group(**Map-3.1**).

Undeformed and unmetamorphosed sedimentary sequence of rocks belonging to Chhattisgarh Super group of Meso to Neo Proterozoic age overlies the granitoids of and rocks of sonakhanGroup.The rocks of Raipur district is represented by Chandi Formation, Gunderdih Formation and Charmuria Formation belonging to Raipur Group of Chhattisgarh Super Group.

Chandi Formation:

Chandi Formation is mostly a calacareous facies with intra-formational arenite found mainly in southern and eastern part of the district covering Dharsiwa and Tilda block and is represented by stromatolitic limestone and dolomite with argillaceous intercalations at places and intercalations with ferruginous glauconitic arenite and purple, friable, splintery and calcareous shale at some other places particularly in southern and central part of Dharsiwa block. The limestone /Dolomite is pink, purple, reddish brown, grey, greenish grey, in colour, fine to medium grained, hard and compact bedded rock. The arenite is reddish brown, brown in colour, fine to coarse grained, cross bedded with micaceous shale partings. Fine grained facies is thinly laminated.

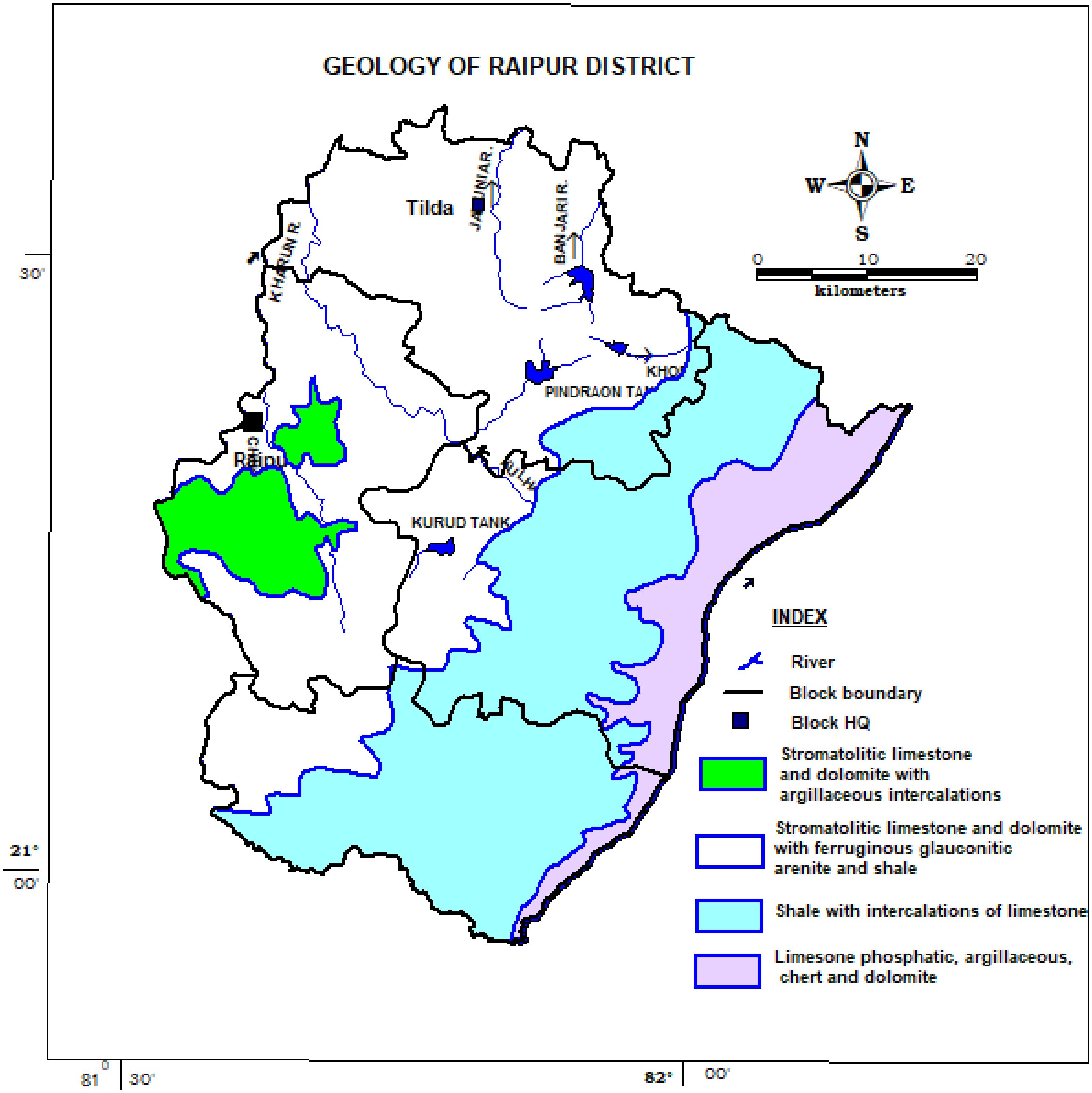
Gunderdehi Formation:

Gunderdehi formation is dominantly a calc-argillite litho facies. This formation is mainly found in south central part of Raipur district covering Abhanpur, Aranng and Tilda block and is represented by calcareous, highly friable, purple shale with intercalations of impersistent stromatolitic limestone bands, and intra formational conglomerate lenses in the upper part.

Charmuria Formation:

Charmuria formation is dominantly a carbonate facies and is represented by phosphatic, argillaceous, cherty and dolomitic limestone and arenite. Limestone is light grey to dark grey, purple in colour, fine to medium grained, bedded to massive, hard and compact rock with intercalations of shale and dolomite, cherty and phosphatic at places. Arenite is brown to reddish brown in colour, medium to coarse grained, ferruginous and glauconitic, thinly bedded with intraformational conglomerate.Charmuria formation is covered in the eastern part of Arang block along the western side of Mahanadi river.

Map-3.1: Geological map of Raipur district, Chhattisgarh



DATA COLLECTION & GENERATION

4.1 Introduction

About 87 nos. of exploratory wells & observation wells drilled by CGWB and through outsourcing in various periods in different formation, 35nos of key observation wells (dug wells, hand pumps and piezometers) established during the survey and 28nos of ground water samples collected from different sources representing shallow as well as deeper aquifers were studied carefully and analysed before preparing the aquifer map and management plan (**Map-4.1**).

4.2 Exploration data

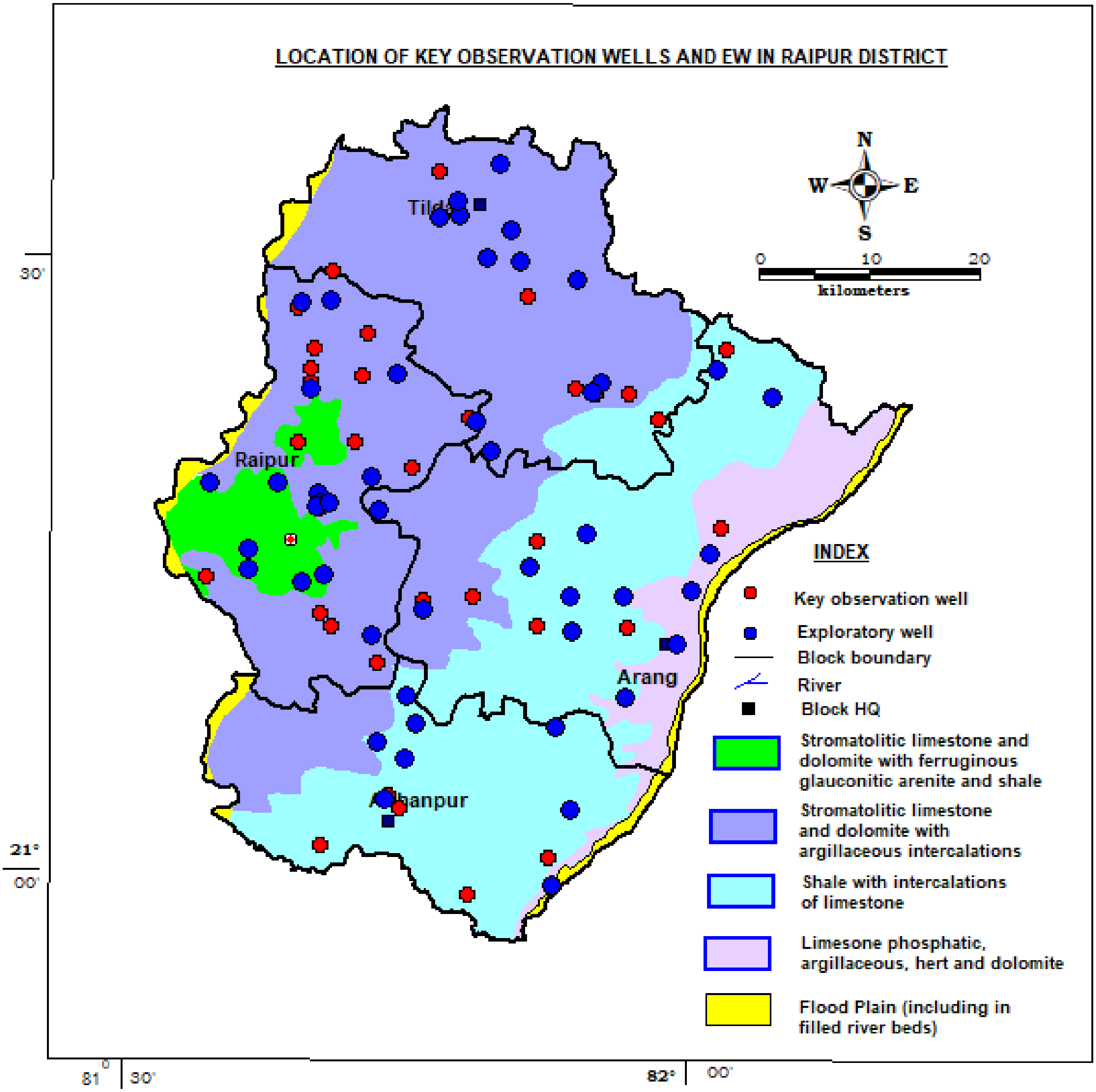
Central Ground Water Board carried out exploration in some parts of the district between 1976-79.Under this program 11 exploratory wells were constructed in Mahanadi command area with an object to explore the ground water occurrence and potentiality in the important hydrogeological unit known as Charmuria limestone.

Exploration was carried out in Raipur district covering consolidated hard Chhattisgarh Supergroup of rocks. Central Ground Water Board has carried out systematic hydrogeological survey in several phases and the last was during 1990-91.The reappraisal survey was carried out in the year of 1994-95, which provided themomentumforotheractivityandtheexplorationoftheconsolidatedformation commencedinAAP1980-81 and continuing.Out of 87 numbers of explorations, CGWB has drilled60nos of EW, 13nosofOW. Also 14nos of piezometers were drilled by CGWB in the district to record the static water level in various periods for shallow and deeper aquifers.The sites for exploration were selected on the basis of hydrogeological investigations that was carried out with the help of geological map, lineament map, geomorphological map based on remote sensing studies and the toposheet no 64 H,G & K of SOI on 1:50,000 scale and also as per the requirement given by State PHED. The ultimate sites were pinpointed with the help of surface geophysical investigations at many points.The aquifer parameter of various shallow and deeper aquifers were calculated based on long term (1000 minutes) pumping tests, preliminary yield test and slug test of bore/tube wells during exploratory drilling. Variable discharge test, SDT (Step draw down test) has been conducted in several wells through three or four steps. The well loss and formation loss components of draw down were calculated by determining the well loss coefficients (B) and formation loss coefficients (C). The well efficiency and specific capacity determined by SDT can also be indicative of hydraulic characteristics of the aquifer. The details of the exploration is given in **Annexure-I**. Thestatusofborewellsdrilledineach blockofthedistrictisshownintable-4.1.

Table-4.1: Status of exploration (EW& OW) in Raipurdistrict (formation wise)

Sl.No	Block	Chandiformation	Gunderdih Shale	Charmuria Limestone	Total
1	Dharsiwa	33	-	-	33
2	Arang	12	12	4	28
3	Tilda	13	-	-	13
4	Abhanpur	-	12	1	13
Total		***38***	***24***	***5***	***87***

Map-4.1: Map showing the location of exploratory wells, key observation wells, Chhattisgarh



4.2.1 Well design

Hard and soft rocks need separate well design. Since Raipur district is mostlycovered by hard rock, so well construction is relatively an easy job. With the help of high capacity DTH rigs, 200 m deep wells can be constructed within 10-12hrs in hard rock areas. In these wells of hard rock, casing the initial weathered thickness is a bit time taking. Once the weathered zone is sealed with casing, drilling through massive formation is just a matter of time. The penetration rates (depth drilled per minute) are high in general.Constraints come whenever there is collapsible fractured zone or crushed breccia struck below massive rock. Drilling through highly cavernous, clay filled zone or zone of very high discharge also produce hindrance to drilling process. Higher the weathered thickness (more than 20-25 m) over massive hard rock need combination rigs to construct a successful well. In such area gravel pack rotary wells have to be constructed to tap the weathered zone. Many a times low yielding hard rock wells are developed for enhancing yield either through hydro-fracturing, blasting or through chemical treatment (particularly for clay filled cavernous zones by sodium hexa meta phosphate). PVC casing is preferred wherever ferric oxide problem persist in ground water of hard rock.

In these wells protective casing of 4” to 6” diameter and length varying from 9 m to 36 m is required for the weathered and collapsible zone (Fig. 2). The cavernous limestone/dolomite sometimes cause drilling problem even after the top weathered zone is cased, due to filling of sticky clay. Sometimes this zone needs casing to complete the drilling operation successfully.

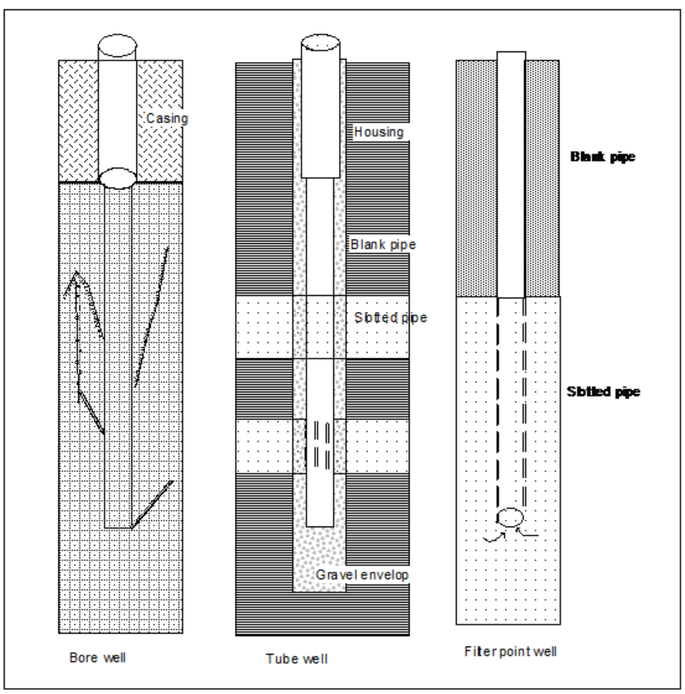


Fig 2 –Well design

Water Level data

Ground water is a dynamic system. It always remains under the influence of time dependant recharging and discharging factors. Due to this continuous influence, water level of the aquifer system fluctuates and the range depends on the period of influence. The recharge to the ground water system is controlled by many factors such as rainfall, seepage from reservoirs, lakes, ponds, rivers and irrigation, etc. The output from the ground water system includes ground water withdrawal, natural seepage to rivers and sea, evaporation from shallow water table and transpiration through vegetation.

Central Ground Water Board started monitoring the ground water regime through the All India National Hydrograph Network Stations from 1969 onwards. The density of observation wells was increased year after year. During the survey 35nos of wells were monitored&studied .

Ground water levels, observed over a period, provides valuable information on the behavior of ground water regime, which is constantly subjected to changes due to recharge and discharge. The difference between these two factors results in the decline or rise in the ground water storage. When the recharge exceeds discharge there will be rise in the ground water storage whereas decline in the storage will be observed when recharge is less than discharge. The response of these factors is ultimately reflected on the water level of the area and their fluctuation. The phreatic water table of an area is the subdued replica of surface topography, which is regionally controlled by the major river basins and locally controlled by the watersheds. This is termed as phreatic aquifer in the report which represents the weathered formation of the area. Since all the developmental activities is listed by administrative unit in the state hence the block wise or district wise water level data is needed for planning developmental activity. Based on analysis of water level data, the changes in the ground water regime have been discussed. For every set of measurement, the data was analyzed and maps like Pre- and post-monsoon depth to water level, Water level fluctuation and Long term (decadal) water level trend have been prepared. The historical water level data available were analyzed to have long-term trend in water level behavior of all the basins within the state. Separate maps were prepared for pre-monsoon and post-monsoon decadal trend. These water level trends were analyzed to understand the ground water regime variation in long-term basis. The details of the water level data is given in Annexure-II.

4.4 Hydrochemical data

The hydrochemical analysis of the ground water of the district was based mostly on the analysis of 28 ground water samples collected during the survey and exploration from key observation wells as well as exploratory wells. The samples were distributed throughout the district representing all the aquifers. The parameters analysed were EC, pH, Ca^{+}, Mg^{+}, Na^{+}, K^{+}, CO_3^{--}, HCO_3^{-}, Cl^{-}, SO_4^{--}, $NO_3^{-}$and F^{-} . These analyses do not represent a particular year or period in a year (pre or post monsoon). During the year 2019,40numbers of ground water samples from ground water monitoring wells of CGWB in Raipur district were analysed for Arsenic.Further, a special study has been taken up by CGWB to assess the Uranium contamination in ground water in the year 2019 where40nos of ground water samples were analysed in the chemical laboratory of CGWB, Lucknow.

All the chemical analyses presented here have been carried out in the laboratory of CGWB, NCCR, Raipur. EC and pH were analysed using EC and pH meters respectively. Ca, Fe, CO_3, HCO_3 and Cl were analysed using titrimetric methods. K and Na were analysed by flame photometer, SO_4 and F by Spectrophotometer, NO_3 by UV Spectrophotometer and Arsenic was analyzed by AAS. The samples which were analyzed for major cation and anion species are balanced electrochemically within +10 percent. The obtained results give the overall existing scenario of the ground water hydrochemistry of Raigarh district. With respect to the results the suitability of ground water for drinking, agriculture and industrial purposes has been described.

The ground water samples were collected in good quality, cleaned and well-washed polyethylene bottles of one litre with necessary precautions. The water samples were divided in two portions. The 1st portion was used for measurement of physical parameters, cations and anions. The 2nd portion was acidified with few drops of ultra pure acid (E. Merck) for analysis of the iron and arsenic. The bottles were labeled with respect to collecting points, date and time in order to avoid any error between collection and analysis. The collected water samples brought to laboratory for determining physicochemical parameters by the standard methods given in APHA 19th edition, 1995. All the chemicals were used AR grade of pure quality. Distilled water was used for the preparation of all the reagents and solutions. The pH measured by using WTW digital pH meter (model 7110) with an accuracy of ± 0.01% and Electrical Conductivity measured by WTW digital Conductivity meter (model 7110) with an accuracy of ± 0.01% respectively. Total hardness and calcium were measured by EDTA complex ometric titration method. Magnesium was calculated by the difference of total hardness and calcium ion concentration (TH - Ca). The sodium and potassium were determined by flame photometer. The carbonate and bicarbonate was measured by titration method and by the obtained concentration of carbonate and bicarbonate, the total alkalinity was computed and reported in mg/l as $CaCO_3$. Chloride was measured volumetrically by silver nitrate titrimetric method using potassium chromate as indicator. Sulphate was measured by spectrophotometer (Cecil) method using barium chloride as precipitating agent. The nitrate was determined by UV-Visible spectrophotometer at 220 nm. Fluoride was determined by ion selective electrode (Orion 4 star) using TISAB solution. The iron was determined in the acidified water samples by ECIL Atomic absorption spectrophotometer (model no. 4141). Arsenic was analysed by the combination of hydride generator and AAS.

To know the suitability of ground water for drinking, irrigation and industrial purposes different methods are used as described below.

The result of the chemical analysis of ground water samples was compared with IS 10500 BIS: 2012 for the drinking purposes. The BIS standard mentions the acceptable limit and indicates its background. It recommends implementing the acceptable limit. Values in excess of those mentioned as "acceptable" render the water is not acceptable, but still may be tolerated in the absence of an alternative source but upto the limits indicate under "permissible limit" in the absence of alternate source, above which the sources will have to be rejected.

The type of ground water is ascertained by the pipe diagram. Ground water always contains some amount of dissolved constituents; their presence affects the soil structure, permeability and aeration which ultimately affect the plant growth. Several factors such as Sodium soluble percentage (SSP), Residual sodium carbonate (RSC), Sodium adsorption ratio (SAR), Percentage sodium (%Na) and Kelly index (KI) are defined for irrigation water suitability . The US Salinity Diagram developed by the US Salinity laboratory in 1954 is an important tool to classifying irrigation water. It is a plot of SAR verses electrical conductivity and used to decide the suitability of ground water for irrigation purposes. Soluble Sodium Percentage (SSP) of the water is calculated by applying the equation given below in which the values are expressed in meq/l. The sodium in water replaces Ca in the soil by Base Exchange process decreasing the soil permeability. Water with less than or equal to 50 SSP value is of good quality and more than 50 is not suitable for irrigation as permeability will be very low.

$$\mathbf{SSP} = (\mathbf{Na}/(\mathbf{Ca} + \mathbf{Mg} + \mathbf{Na})) * \mathbf{100}$$

The concentration of carbonate and bicarbonate also plays a very vital role for classification of irrigation water. The relative abundance of sodium with respect to excess of carbonate and bicarbonate over alkaline earth also affects the suitability of water for irrigation purpose and this excess is denoted by residual sodium carbonate (RSC) and is determined by the formula as given, where all ions in meq/l.

$$\mathbf{RSC} = (\mathbf{HCO_3} + \mathbf{CO_3}) - (\mathbf{Ca} + \mathbf{Mg})$$

The most common measure to assess sodicity in water and soil is called the Sodium Adsorption Ratio (SAR). The SAR defines sodicity in terms of the relative concentration of sodium (Na) compared to the sum of calcium (Ca) and magnesium (Mg) ions in a sample. The SAR assesses the potential for infiltration problems due to a sodium imbalance in irrigation water.

$$\mathbf{SAR} = \mathbf{Na}/\sqrt{(\mathbf{Ca} + \mathbf{Mg})/\mathbf{2}}$$

Percentage sodium (%Na) is an indication of the soluble sodium content of the groundwater and also used to evaluate Na hazard. In all natural waters, %Na is a common parameter to assess its suitability for irrigation purposes since sodium reacts with the soil to reduce permeability.

$$\%Na = ((Na + K) / (Ca + Mg + Na + K)) * 100$$

Kelly's ratio (KR) introduced by Kelly, is an important parameter used in the evaluation of water quality for irrigation. This parameter is based the Na, Ca and Mg levels in the groundwater. According to this classification, groundwater with a KR value greater than one (>1) is deemed unfit for irrigation.

$$KI = Na/(Ca + Mg)$$

Corrosivity ratio CR are used to know the suitability of water for irrigation purpose. Here it is used for industrial water suitability in ground water of Chhattisgarh. Corrosivity ratio (CR) indices formula is described below. The Corrosivity ratio (CR) is calculated using the under mentioned formula in which the ions are in mg/l units. The groundwater with corrosivity ratio <1 is considered to be safe for transport of water in any type of pipes, whereas >1 indicate corrosive nature and hence not to be transported through metal pipes and it is not suitable for industrial or domestic purposes.

$$CR = (Cl/35.50) + (SO_4/96) / (CO_3 + HCO_3)/100$$

4.5 Achievement

To understand the regional hydrogeological behavior of Raipur district, this complex aquifer setup has been classified into aquifer system on the basis of their lithology and age. The aquifer characteristics, its extent and the ground water quality are analyzed on the basis of these broad classifications. Ground water flow pattern, long and short term dynamics is also studied block wise. Finally the Aquifer maps were prepared and accordingly Aquifer Management Plan has been formulated for Raipur district.

AQUIFER DISPOSITION

5.1 Principal andMajor aquifer groups

The aquifer material controlling ground water flow in the district can be broadly divided into two major media(1) Porous media (Phreatic Aquifer) and(2) Fractured media (Deeper Aquifer). The principal aquifer groups in Raipur district is:

(i) Chhattisgarh Super group

(i) Chandi Limestone

(ii) Gunderdih Shale

(iii) Charmuria Limestone

The major aquifer groups in Raipur district are in**Map-5.1**:

The phreatic aquifer both in hard and soft rocks in the district iswide spread and largely in use. This aquifer is being tapped mainly through dug well upto a depth of 20 m broadly. However, extraction of ground water is done at many places by tapping dug cum bore wells or shallow bore wells drilled to a depth of 60 m that generally represents shallow aquifer which is generally connected to phreatic aquifer. The weathered mantle and shallow fractures mainly constitute the shallow aquifers. The thickness of weathered mantle varies from 4 to 34 mbgl. Nearly 90% of dug wells are in the depth range between 5 and15 mbgl. The hand pumps installed by PHED for drinking water taps the shallow fracture zone down to 60 m bgl. The alluvium deposits in the area are mainly confined all along with the flood plains on either side extending 2 km at places. These comprise mostly gravels, coarse to medium sand and silts. It attains a thickness of 10 to 20 m along Kharun and Seonath River. A major part of the central part of the district (Naya Raipur and its adjoining area) is represented by lateritic horizon which constitute a potential phreatic aquifer suitable for construction of large diam dug wells. From the data collected, the characteristic of different aquifers in the district are deciphered and described in the following table-5.1:

Table-5.1: Aquifer Parameters of phreatic aquifers in different formations in Raipur district

Aquifer	**Specific capacity (lmp/day)**	**Transmissivity (m^2/day)**
GunderdehiShale	403	60
Charmuria shale	51.5	40.75
Chandi Limestone	160	96

The shallow and deeper aquifer (fractured aquifer) in Raipur district is represented by(a) Chandi formation and (b) Gunderdehi formation and (iii) Charmuria formation belonging to Raipur group of Chhattisgarh super group which are generally un-metamorphosed, structurally less disturbed Meso-Neo proterozoic sediments. These are horizontally bedded non-fossiliferous formations. To decipher the aquifer characteristics of these formations,87 numbers of exploratory wells are drilled by Central Ground Water Board in various FSP and through outsourcing. The status of exploration and the findings of exploration in terms of aquifer characteristics are described in the following:

STATUS OF EXPLORATION IN RAIPUR DISTRICT

Central Ground Water Board carried out exploration in some parts of the district between 1976-83 with an object to explore the ground water occurrence and potentiality in the important hydrogeological unit known as Chandi and Charmuria limestone. The depth of exploration of ground water through drilling was restricted to a range between 22 to 90 mbgl. Most of the wells drilled ended either in Charmuria limestone or limestone and dolomite of Raipur group. To explore the ground water potential in deeper aquifer Central Ground Water Board again carried out exploratory drilling program under various FSP from 1976 to 2021.

So far 87 bore wells (60 exploratory wells ,13 observation wells, 14 piezometers) have been drilled in the study area (Fig- 4.1). The status of borewells drilled in Raipur district is shown in table 5.2 and 5.3. Based on the information collected during exploration a potential map has been prepared for the district. (Fig 6.4)

Table 5.2: THE STATUS OF BOREWELLS DRILLEDIN RAIPUR DISTRICT

Sl.No	Block	Chandi formation	Gunderdih Shale	Charmuria Limestone	Total
1	Dharsiwa	35	1	0	36
2	Arang	12	9	4	25
3	Tilda	13	0	0	13
4	Abhanpur	0	12	1	13
	Total	***57***	***25***	***5***	***87***

Table:5.3- SALIENT FEATURES OF EXPLORATORY DRILLING IN RAIPUR DISTRICT

Formation	**Noof Borewells**	**DepthRange (mbgl)**	**Casing (mbgl)**	**Discharge in lps in no of Wells (lps)**					**Draw Down (m)**	**Transmissivity**
				<1	***1-3***	***3-5***	***5- 10***	***>10***		
Chandifm	60	32.08 – 304.4	4-34	20	16	11	7	2	0.25 50	2.1 – 121.7
Gunderdehi fm	22	50-300.6	5.5-20.1	10	4	2	1	0	10 - 50	6.02 –55.87
Charmuria fm	5	50-200.17	11.5-16.5	2	3	0	0	0	19.6	4.19
Total	***87***	***32.08 - 304.4***	***4-34***	***32***	***23***	***13***	***8***	***2***	***0.25-50***	***2.1-121.7***

FINDING OF GROUND WATER EXPLORATION

The district is underlain mainly by three distinct geological formations in the age group of Meso to Neo Proterozoic. The Chandi formation of Raipur group of Chhattisgarh Supergroup occupies major parts of the district comprising of stromatolitic limestone and dolomite with argillaceous intercalations at places and intercalations with ferruginous glauconitic arenite and purple, friable, splintery and calcareous shale at some other placesinthe western part of the district. A thin layer of alluvium / laterite belonging to the Quaternary age occur along the floodplanes of major rivers and its tributaries.

The alluvial deposits in the area are mainly restricted to flood plains, on either side extending 2 km at places. These comprise mostly gravels, coarse to medium sand and silts. It attains a thickness of 10 to 20 mts along Kharun, SeonathJonk& Mahanadi River. Areas where water table is shallow and thickness of the alluvium is more, form potential aquifers with yield upto10lps for drawdown within 6m.(Paragaon and Pokhara exploratory wells).

From the study of the geological cross section (fig 6.2 A & B) it is clear that the maximum thickness of Gunderdehi formation is in central part of the district while eastern parts are covered with older formations.The basement of the district is Chandrapur sandstone found in the eastern part of the district.In general the dip is towards NW in the area. Exploratory wells drilled in district shows that the potential aquifers are generally encountered within the depth of 55m bgl.Thesummerised information is given in table –5.4. In Chandi formation the potential zone have been developed due to the formation of secondary porosity and are encountered within 90 mbgl. At few places deeper aquifers are also encountered down to 120 m depth with a yield ranging negligible to 13 lpslps.

S.No.	Geological formation	No of Bore Wells drilled	Drilled depth (mbgl)	Potential zone encountered (mbgl)	Discharge range (lps)	Average discharge of well in lps
1.	Chandi	60	32.08 –304.4	17-25, 30-39, 67-70, 80-83,	0.2 – 13.14	< 5.00
2.	Gunderdehi	22	50-300.6	21-37, 64-66	0.5 - 10	< 3.0
3.	Charmuria	5	50-200.17	25-30, 47-51, 66-69, 82-85	1 – 1.75	< 2

Aquifer Characteristics of different formations

Chandi Formation: The Chandi formation Covers an area of 1600 sq. km in eastern parts of district mainly in Arang block and partly in Abhanpur block. The ground water occurrence in these areas is in phreatic or semi-confinedcondition. The potential zones have been developed due to extensive karstification and solution action down to 90mbgl. The discharge obtained from the wells drilled in Chandi formation varies from 0.2 to 13.14 lps.Generally, one to two nos of potential fracture zones are encountered in the depth range of 20 to 90mbgl. Depth to a water level in bore wells varies from 1.2 to 25mbgl. The casing depth varies from 4 to 34mbgl. The casing length also indicates thickness of the weathered formation. The highest discharge of 13.14lps was obtained at old RGI campus.

Gunderdehiformation: TheGunderdehi formation in the district has occupied the central part of the district, west of Mahandi River covering an area of 1012 sq. km. This formation is mainly argillaceous in nature consisting of shale, bedded, purple in colour, with intercalation of calcareous and dolomitic shale, which behaves as acuiclude layer with the underlying aquifer of Charmuria limestone. These shales are impervious in nature behave as aquiclude. However, the presence of impersistent stromatolitic limestone bands, and intra formational conglomerate lenses in the upper part, some bore wells yielded more than 3 lps. The transmissivity, permeability and storativity is very poor. The discharge obtained from the wells drilled in the Gunderdehi formation varies from 0.5 to 10 lps.Generally, one to two sets of potential fracture zones are encountered in the depth range of 40mbgl. Depth to a water level in bore wells varies from 1.3 to 30.8mbgl. The casing depth varies from 5.5 to 20.1mbgl. The casing length also indicates thickness of the weathered formation. The highest discharge of 10lps was obtained at Bhansoj village in Arang block.

Charmuriaformation: Thecharmuria formation covering an area of 268sq. km mostly the western part of the district in Tilda, Dharsiwa and part of Abhanpur district occurs as thick massive sequence of argillaceous limestone, and cherty limestone, flaggy in nature & bedded. The upper unit of the charmuria formation is argillaceous in nature and thus the effect of solution activity is negligible. This upper unit is devoid of any primary as well as secondary porosity and behaves as aquifuge. The middle and lower part of the charmuria, specially the Ranidhar member is represented by the white cherty limestone which is very sensitive to solution action and thus has developed potential aquifers. The average yield of the open wells ranges between 15 to 30 m^3/day with a specific capacity of 25 lpm/m of drawdown. The potential fracture zones are encountered in the depth range of 50mbgl The casing depth varies from 11.5 to 16.5mbgl. The casing length also indicates thickness of the weathered formation. The discharge obtained from the wells drilled in the Charmuria limestone varies from 1 to 1.75lps. The upper most partof Charmuria formation is argillaceous / shaley in nature while limestone represents lower unit. This formation form good aquifers duetokarstification. But very few bore wells are drilled in this formation in the district. This formation may be explored more for having good potential zones as evident from neighboring districts.

Discussion: Chandi&Charmuria formation do exist to create secondary porosity in the younger limestone / dolomite formation whose width range from few centimeters to as much 2.5 m. The geometrical configuration of the network of solution cavities in limestonehas a profoundandcontrollingeffectontheground water yield.Stromatolitic limestone and dolomite form the potential aquifers. They are hard contact and massive and ground water occurs in them along joints, fractures and bedding plains under phreatic conditions. These rocks show secondary porosity and permeability due to dissolution effect along joints fractures and bedding planes. The hydraulic conductivity of these rocks vary in vertical and lateral directions. Karstic features like sink holes and swallow holes of various shape and dimensions are quite prominantly developed in this unit as exo-karsts.

The field investigations have brought to light the fact that due to even bedding planes and more or less homogenous nature of dolomite, karstification has been along bedding planes, which act as suitable avenues for lateral movement of ground water.

In the limestone the solution opening is more widespread so as to form a network of interconnected openings. The karstification controlled by major joint pattern trending ENE-SWS direction. Further the hydrogoeogical properties of the rock units overlying and underlying the carbonate rocks are such that ground water moves laterally and is channeled to create maximum dissolution of the carbonate rocks. This results in interconnected cavernous zones to act as master conduit system, confining the ground water pressure conditions.Although the fracture and cavernous zones are seen over a major part of the area, they may be localized, and their permeabilities are several orders of magnitude larger than unfractured rocks. If these fractures or cavernous system are not continuous or intersect each other's laterally, they may be just hydraulically isolated from ground water circulation.

In hard rocks areas the thickness of the aquifer zones varies from a few centimeters to a few meters and especially the aquifers at the contact zones are very thin. Further it has been observed that though certain wells have given good yields, other wells drilled to the same depth within a hundred or a few hundred meters distance from these successful wells were found to be either dry or yielding very poor discharge. This clearly indicates the limited regional extent of the aquifer zones.

Due to this erratic and limited nature of the aquifer zones in the area, it is possible that certain wells, when tested or pumped for short duration may yield good amount of water but may not withstand with continuous long duration of pumping. To evaluate this aspect, the variation of specific drawdown with time for a number of wells based on the pump test data and aquifer parameter have been analysed.

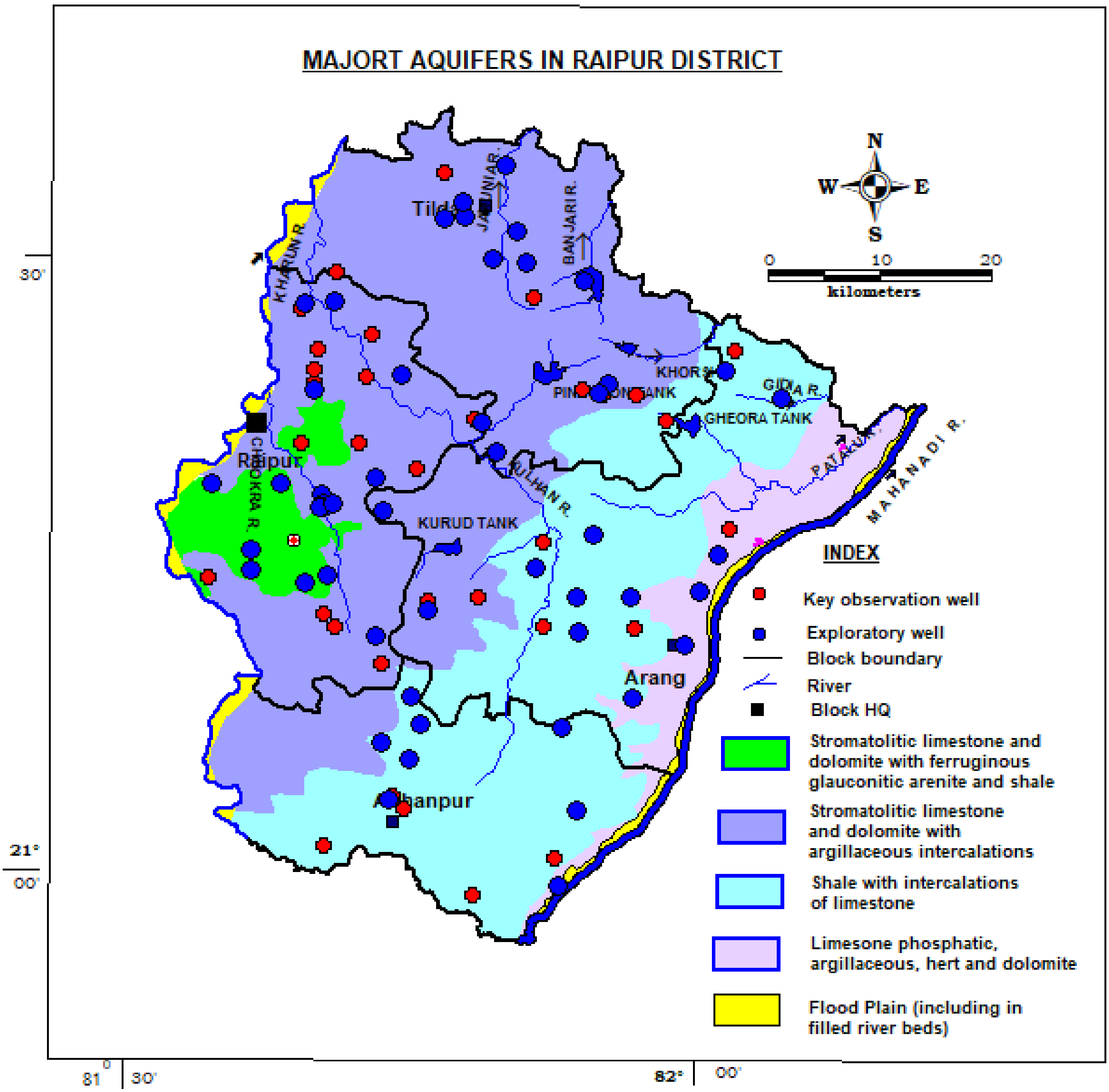
Optimum discharge for each well to be obtained from a well test includes location of the static water level the yield and the depth or water when the well is being pumped at different rates from these data the drawdown the yield and specific capacity that is the yield per meter of drawdown can be computed. In deep wells tapping substantial thickness of the water bearing medium the yield is almost direct proportional to the drawdown. This however is not true in general for shallow wells.

In overall, it may be deciphered from the study that in Raipur district, limestone and dolomite form the main aquifer system in the area. Charmuria limestone and Gunderdehi shale are not very good yielding. Cavernous limestone of Chandi formation has been identified as potential and prolific aquifer system in the district that can afford sustainable ground water development. The aquifer canbe divided into two zones shallow and deeper aquifers. The sustainability of the shallow zones in hard rocks particularly in the bore wells tapping Chandi Formation in Dharsiwa block are under threat.Many dug wells and hand pumps get dried up during summer.The alluvium blanket along the major rivers also forms good repository of ground water.However, the lateritic cover forming the phreatic aquifer behaves a good aquifer zone. Perusal of fence diagram shows that these hydrogeological units show gradational facies change intheir lithological compositions, therefore intercalations and inter tonguing of argillaceous material with arenaceous and calcareous material is quite preponderant. Thus, limestone cavities get filled up with clay, interbedding with orthoquartze sandstone and shale affecting the extent and degree of karstification in the limestone. Exploratory drilling has brought out the fact that the limestone cavities have been developed within the depth range of 90m (shown in hydrogeological map of the district (Map:6.3).

The generalized yielding capacity of existing irrigation tubewells, tapping different geological units, operational in the district area is summarized below and depicted in the following figure.

S.No.	Hydrogeological unit	Ground water yield/ discharge range
1.	River deposit	400 to 800 m^3/day
2.	Newari & Limestone and upper Charmuria	80 to 250 m^3/day
3.	Gunderdehi	10 to 80 m^3/day
4.	Ranidhar member of Charmuria	250 to 100 m^3/day
5.	Lower Charmuria	400 to 800 m^3/day

Map-5.1: Map showing major Aquifer groups in Raipur district, Chhattisgarh



5.2 Ground Water Regime monitoring:

During the study, 35 nos. of wells both dug wells and hand pumps were established and water levels monitored both in pre-monsoon and post-monsoon period(**Annexure-II**).including water quality during pre-monsoon period. The water level analysis data indicates that the static water level in the district varies from 1.9 to 18.54mbgl in pre-monsoon, from 0.77 to 10mbgl in post-monsoon period. The fluctuation varies from 1.12 to 14.1 m. The water level map prepared for the district is presented in (**Map-5.2 A, B&C**).

5.2.1<u>Decadal Ground Water level fluctuation:</u>

The historical water level data from 2009 to 2019 were analyzed to have long-term trend in water level behavior in Raipur district(Table-5.4 A & B,**Map-5.3 A & B**).The table shows that during pre-monsoon period , 57% of wells shows decling trend to the tune of 0.08 to 10.7 cm/yr. However only one well at Abhanpur (deeper zone) shows significant fall. The Pre-monsoontrend shows that 43% of wells show rise of water level to the tune of 0.6 to 5.4 cm/yr. Similarlythe Post-monsoontrend shows 71 % of wells show falling trend to the tune ofof0.1 to 4.5 cm/year &29% of wells show rising trend to the tune of 0.2 to 1.3 cm/yr respectively. The declining trend in post-monsoon period may be attributed to the decline in ground water recharge which may be because of decline in rainfall as well as reducing trend of ground water recharge worthy area.However the ground water trend analysis indicates that there is no significant decline or no significant rise of ground water level (20 cm per year) in Raipur district.The hydrograph of some of the wells are presented in **Fig-4 A to D**.

The overall scenario shows shift in water use from phreatic to semi-confined zone and increased draft for irrigation purpose in selected pockets of Dharsiwa and Tilda blocks. The statistical analysis shows that about67% of total ground water extraction is done in Dharsiwa block tapping dolomite-limestone belonging to Chandi formation. The table-5.4(A&B) gives the ground water level trend (2009-2019) in Pre-monsoon and post monsoon period respectively.

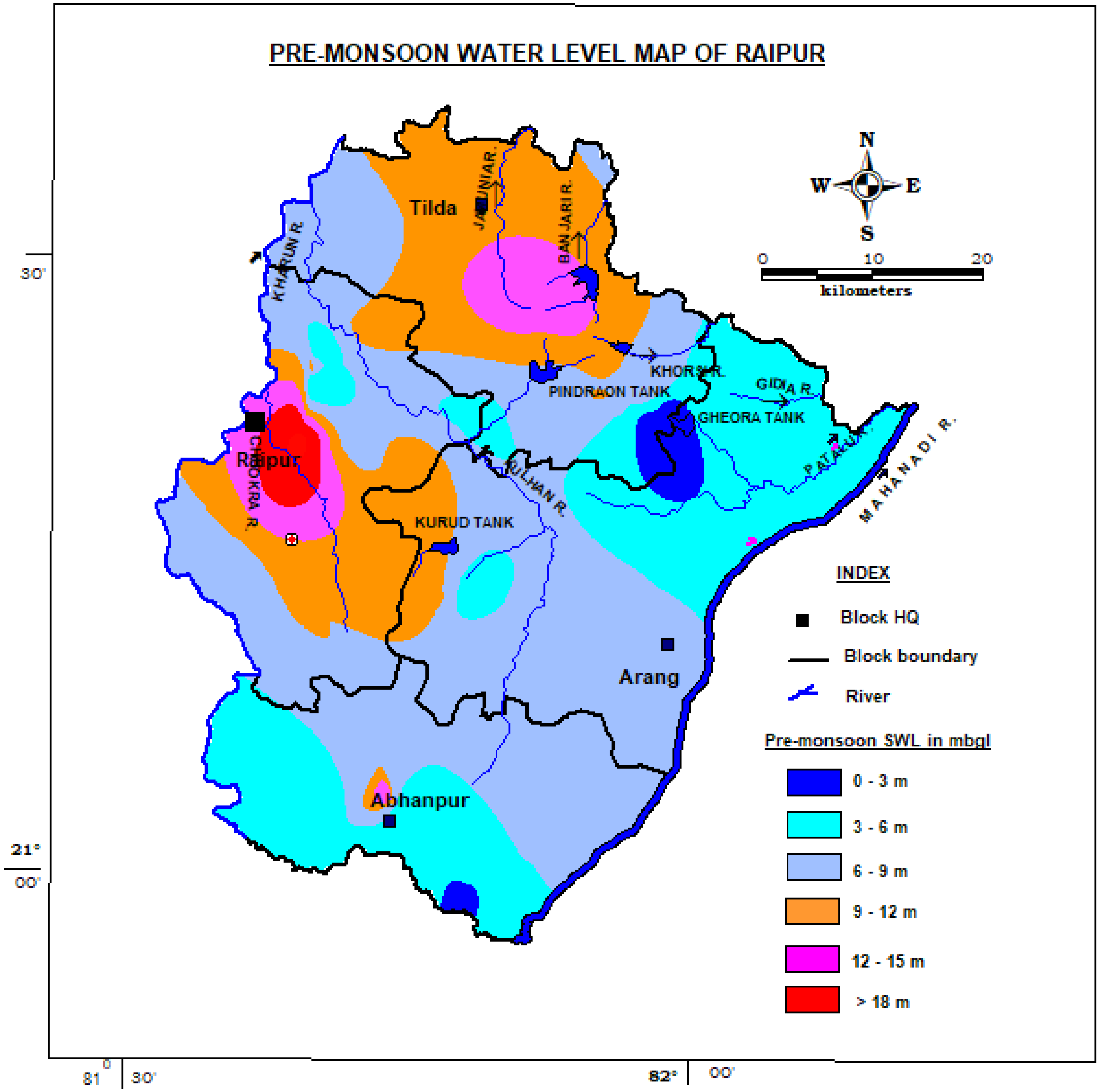
Table-5.4 A: Ground water level trend (2009-2019) in Pre-monsoon period in Raipur district

Sl. No	Block	Location	Long	Lat	Pre-Trend (2009-2019)	Remarks
1	Abhanpur	Bajrangpur	81.8111111	20.9833333	-0.000854	**Declining**
2	Abhanpur	Abhanpur	81.7458333	21.05	-0.048718	**Declining**
3	Abhanpur	Abhanpur S	81.7388889	21.0583333	-0.02498	**Declining**
4	Abhanpur	Abhanpur D	81.7388889	21.0583333	-0.107461	**Declining**
5	Arang	Arang	81.975	21.1944444	0.00658	**Rising**
6	Dharsiwa	Dumartarai	81.6897222	21.1977778	0.007937	**Rising**
7	Arang	Umaria station	81.8666667	21.2	-0.00765	**Declining**
8	Dharsiwa	Devpuri	81.6777778	21.2083333	0.02752	**Rising**
9	Arang	Mandirhasud	81.7666667	21.2208333	0.023597	**Rising**
10	Dharsiwa	Raipur	81.6208333	21.2444444	-0.004552	**Declining**
11	Arang	Ranisagar	82.0280556	21.2783333	0.026935	**Rising**
12	Dharsiwa	Semariya	81.7622222	21.3302778	0.027304	**Rising**
13	Dharsiwa	Saragaon	81.8069444	21.3666667	-0.017282	**Declining**
14	Tilda	Kharora	81.9208333	21.3875	0.030872	**Rising**
15	Tilda	Kanki	81.9919444	21.4002778	-0.016461	**Declining**
16	Dharsiwa	Dharsiwa	81.6722222	21.4083333	-0.058576	**Declining**
17	Dharsiwa	Raita Satna Ni Para	81.7175	21.4427778	-0.049592	**Declining**
18	Dharsiwa	Pandan Bhata	81.6633333	21.4633333	-0.049849	**Declining**
19	Tilda	Chicholi	81.865	21.4658333	0.054267	**Rising**
20	Tilda	Tarpongi	81.6891667	21.4905556	0.00106	**Rising**
21	Tilda	Chanderi	81.7466667	21.4975	-0.033569	**Declining**

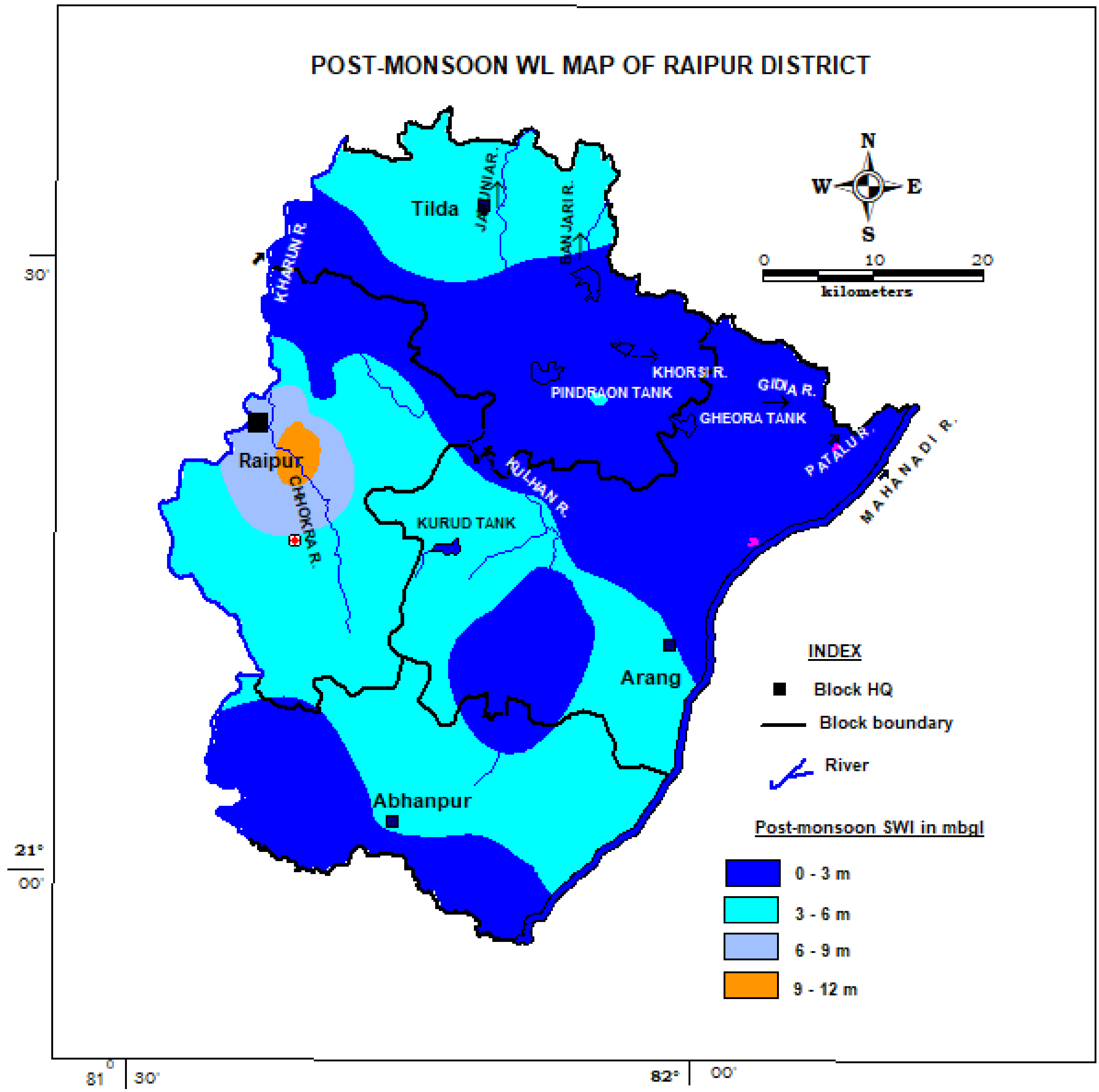
Table-5.4 B: Ground water level trend (2009-2019) in Post-monsoon period in Raipur district

Sl. No	Block	Location	Long	Lat	Post-Trend (2009-2019)	Remarks
1	Abhanpur	Bajrangpur	81.81111	20.98333	0.009096	Rising
2	Abhanpur	Abhanpur	81.74583	21.05	0.013891	Rising
3	Abhanpur	Abhanpur S	81.73889	21.05833	0.005282	Rising
4	Abhanpur	Abhanpur D	81.73889	21.05833	0.008151	Rising
5	Dharsiwa	Manabasti	81.72917	21.16667	-0.007779	Declininhg
6	Arang	Arang	81.975	21.19444	-0.019642	Declininhg
7	Dharsiwa	Dumartarai	81.68972	21.19778	-0.014331	Declininhg
8	Arang	Umaria station	81.86667	21.2	-0.021745	Declininhg
9	Dharsiwa	Devpuri	81.67778	21.20833	-0.003458	Declininhg
10	Arang	Mandirhasud	81.76667	21.22083	-0.045424	Declininhg
11	Dharsiwa	Ravi Shankar University Raipur	81.58389	21.23944	-0.009623	Declininhg
12	Dharsiwa	Raipur	81.62083	21.24444	0.013515	Rising
13	Arang	Ranisagar	82.02806	21.27833	0.007025	Rising
14	Dharsiwa	Semariya	81.76222	21.33028	-0.010636	Declininhg
15	Dharsiwa	Mandhar	81.58389	21.35278	-0.016594	Declininhg
16	Tilda	Kasarangi New	81.97972	21.36556	-0.001638	Declininhg
17	Dharsiwa	Saragaon	81.80694	21.36667	-0.006372	Declininhg
18	Tilda	Kharora	81.92083	21.3875	-0.009278	Declininhg
19	Dharsiwa	Charauda	81.67278	21.39806	-0.005515	Declininhg
20	Tilda	Kanki	81.99194	21.40028	0.002496	Rising
21	Arang	Bhaisa	82.0275	21.40556	-0.011696	Declininhg
22	Dharsiwa	Dharsiwa	81.67222	21.40833	-0.006946	Declininhg
23	Dharsiwa	Raita Satna Ni Para	81.7175	21.44278	-0.009047	Declininhg
24	Dharsiwa	Panderbhata S	81.6525	21.46278	-0.036984	Declininhg
25	Dharsiwa	Pandan Bhata	81.66333	21.46333	-0.035645	Declininhg
26	Tilda	Chicholi	81.865	21.46583	-0.008413	Declininhg
27	Tilda	Tarpongi	81.68917	21.49056	-0.014774	Declininhg
28	Tilda	Tatibandh MVM	81.79056	21.715	0.00558	Rising

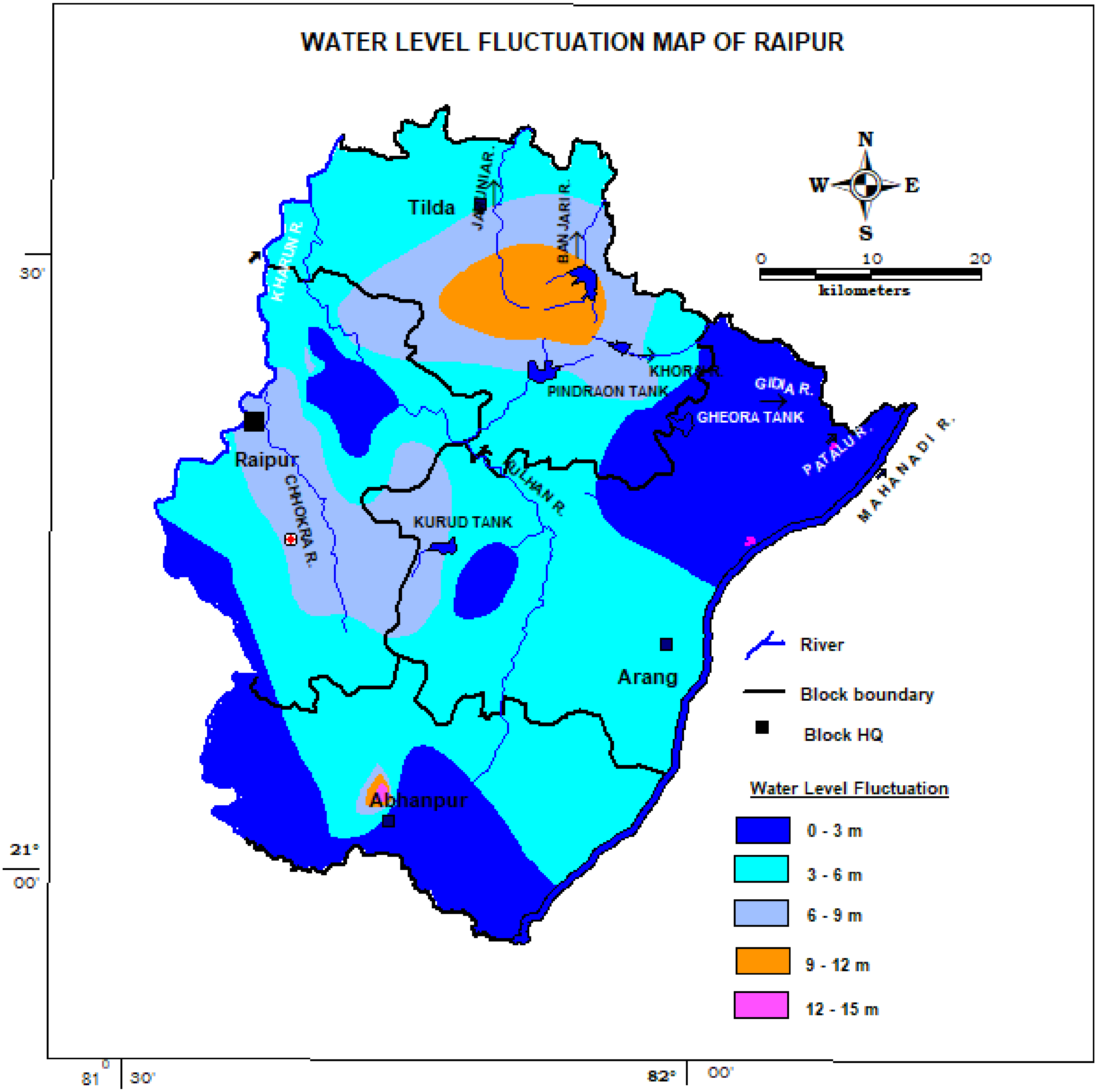
Map-5.2 A: Pre-monsoon water level map of Raipur district, Chhattisgarh



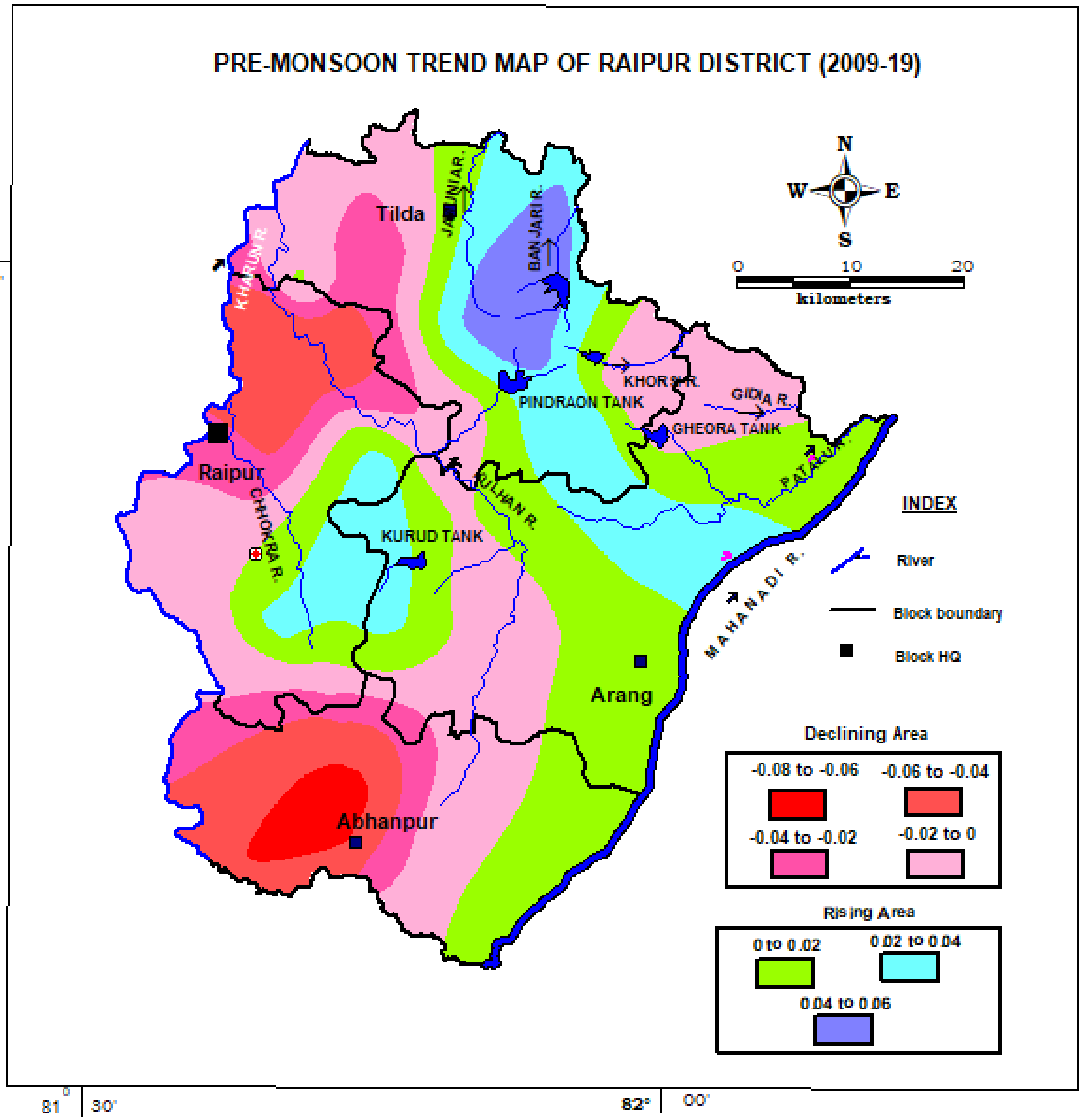
Map-5.2 B: Post-monsoon water level map of Raipur district, Chhattisgarh



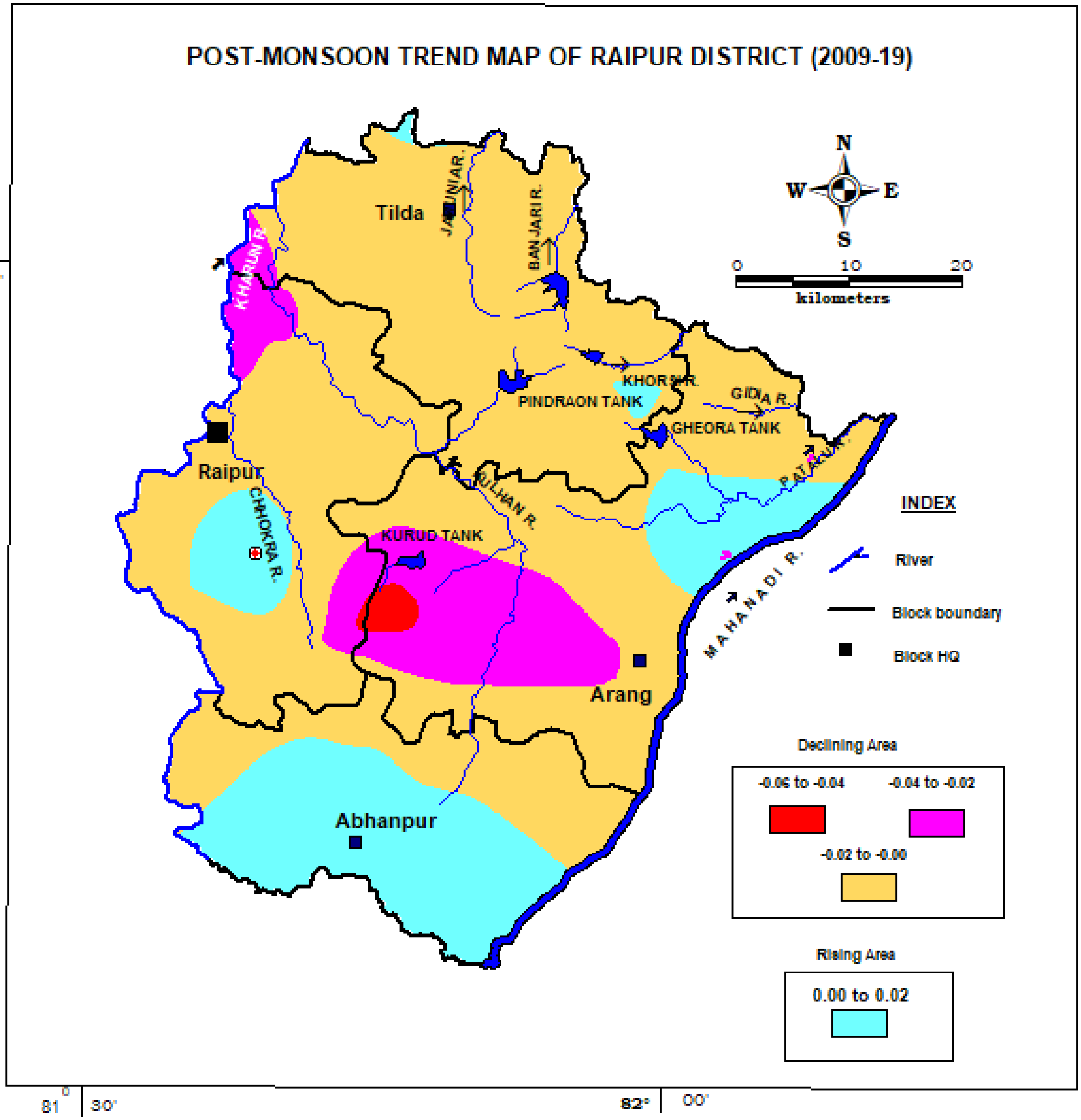
Map-5.2 C: Water level fluctuation map of Raipur district, Chhattisgarh



Map-5.3 A: Long term trend map for Pre-monsoon period of Raipur district, Chhattisgarh



Map-5.3 B: Long term trend map for Post-monsoon period of Raipur district, Chhattisgarh



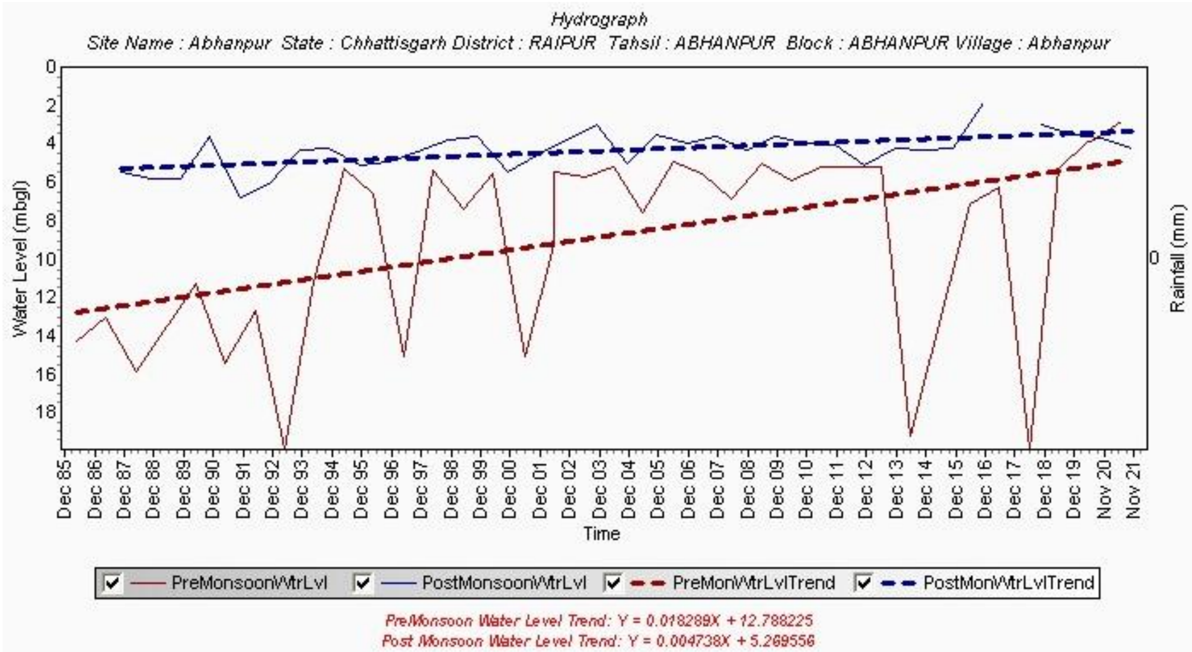


Fig-4.1 A: Hydrograph of Abhanpur

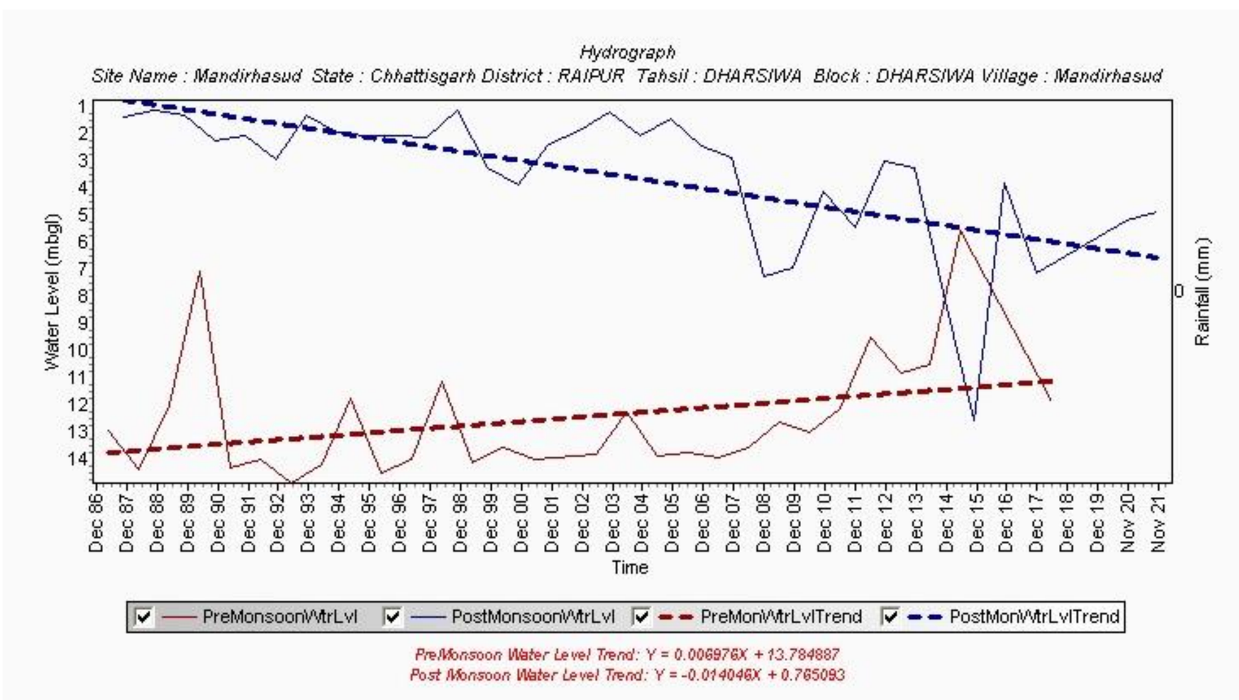


Fig-4.1 B: Hydrograph of Mandirhasaud

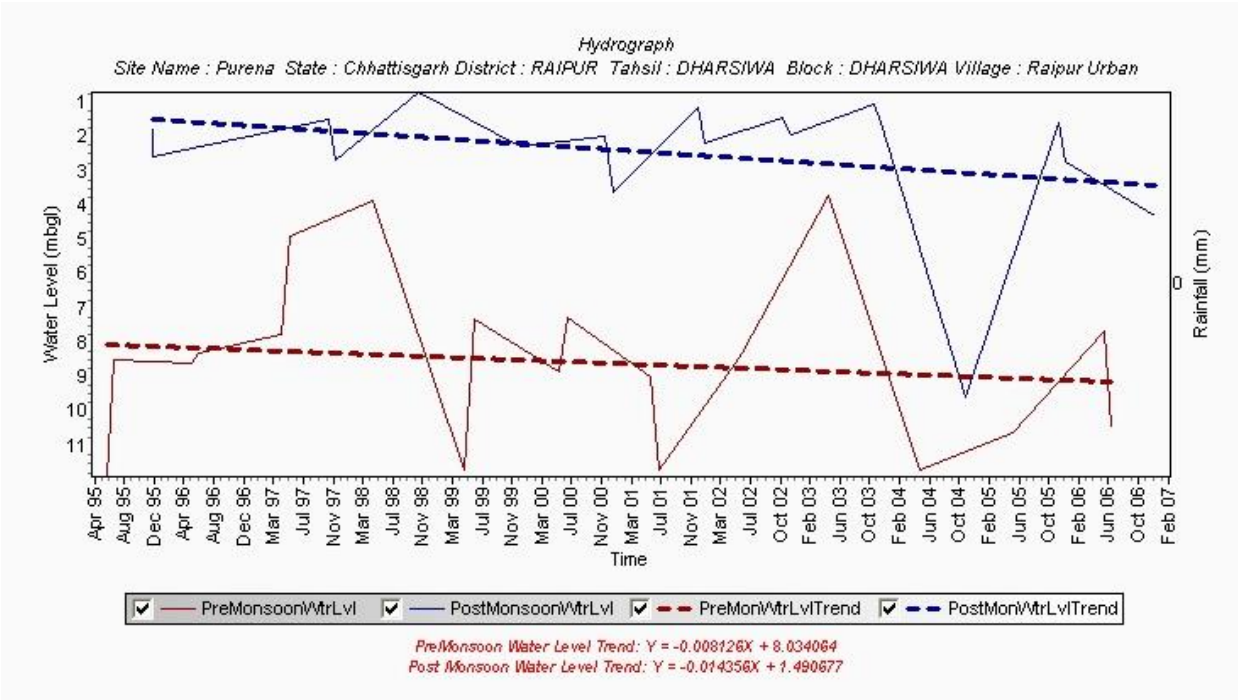


Fig-4.1 C: Hydrograph of Purena

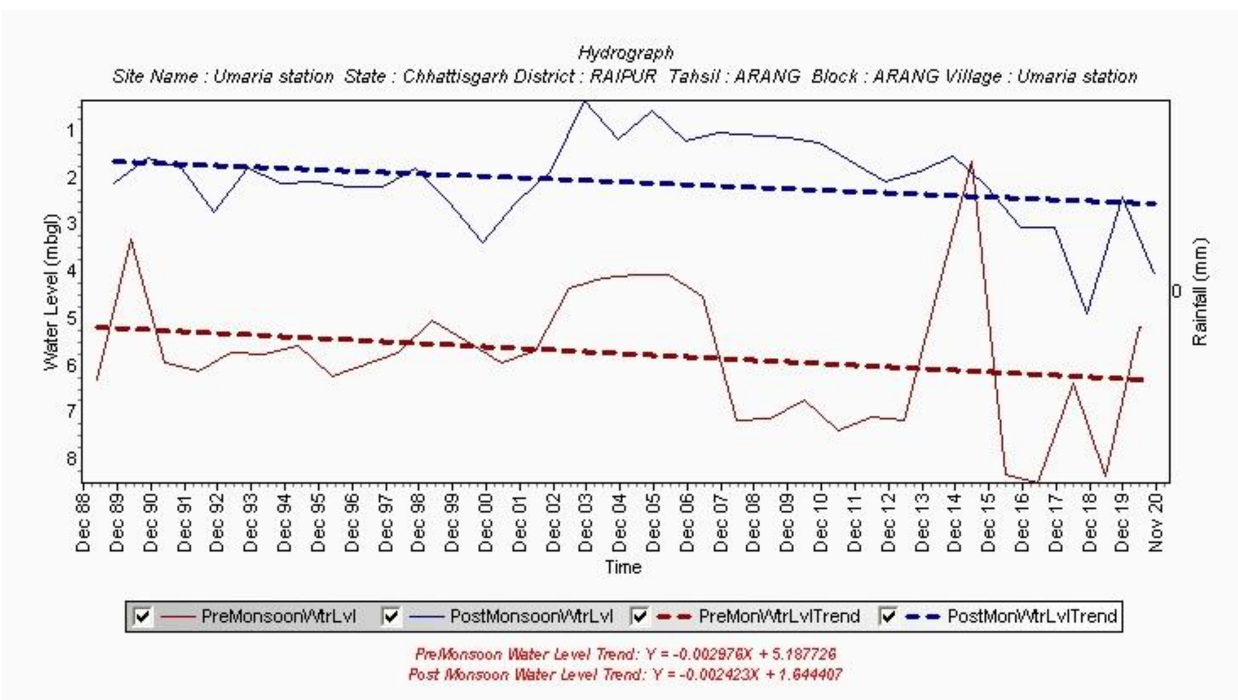


Fig-4.1 D: Hydrograph of Umaria

5.2.3 Ground Water flow direction:

The regional ground water flow direction is towards north (**Map-5.4**). In eastern part of the district the ground water flow direction is towards east. In the eastern and western part, the contours are comparatively broader indicating the flatness of the terrain thereby the gradient of ground water flow is low in comparison to the other part of the district. It may also be seen that the flow of ground water is mostly towards the major drainage suggesting that the base flow is towards the drainage system.

5.3Ground Water Resources:

The ground water Resources of Raipur district has been estimated on the basis of revised methodology GEC 2017. Ground water resources have two components – Replenishable ground water resources or Dynamic ground water resources and Static resources.

5.3.1Replenishable ground water resources or Dynamic ground water resources:

As per resource estimation March 2020, the Annual Extractable Ground Water Recharge (Ham) in the district is 42499.6ham. The Net Ground Water Availability for future use is 13585.14ham. Current Annual Ground Water Extraction for all purposes is 28,840.83ham out of which 20,776.86ham is for irrigation. The overall Stage of Ground Water Extraction in the district is 68.23%.Dharsiwa(90.27%) has the highest stage of ground water extraction while Abhanpur (52.58%) has the lowest stage of ground water extraction. The Annual GW Allocation for domesticuse as on2025 is8179.69 ham with highest quantity in Abhanpur block and lowest in Dharsiwa block. The Net Ground Water Availability for future use is 13,585.14 ham. The block wise resource is presented in **Map-5.5**and table 5.5.

Table-5.5: Block wise Resources as estimated in 2017 of Raipur district (2020)

Sl. No	Block	Annual Extractable Ground Water Recharge (Ham)	Current Annual Ground Water Extraction (Ham)				Annual GW Allocation for for Domestic Use as on 2025	Net Ground Water Availability for future use	Stage of Ground Water Extraction (%)	Categorization (OE/Critical/ Semi critical/ Safe)
			Irrigation use	Industrial use	Domestic use	Total Extraction				
1	Dharsiwa	9697.06	3896.74	380.8	4476.19	8753.73	918.8	918.8	90.27	Critical
2	Arang	12493.39	6659.44	347.76	885.47	7892.67	1055.17	4431.02	63.17	Safe
3	Tilda	10585.63	5905.44	549.5	626.73	7081.68	696.5	3803.94	66.9	Safe
4	Abhanpur	9723.52	4315.24	72.91	724.6	5112.75	903.99	4431.38	52.58	Safe
Total		42499.6	20776.86	1350.97	6712.99	28840.83	3574.46	13585.14	68.23	

5.3.2 Static Ground Water Resources:

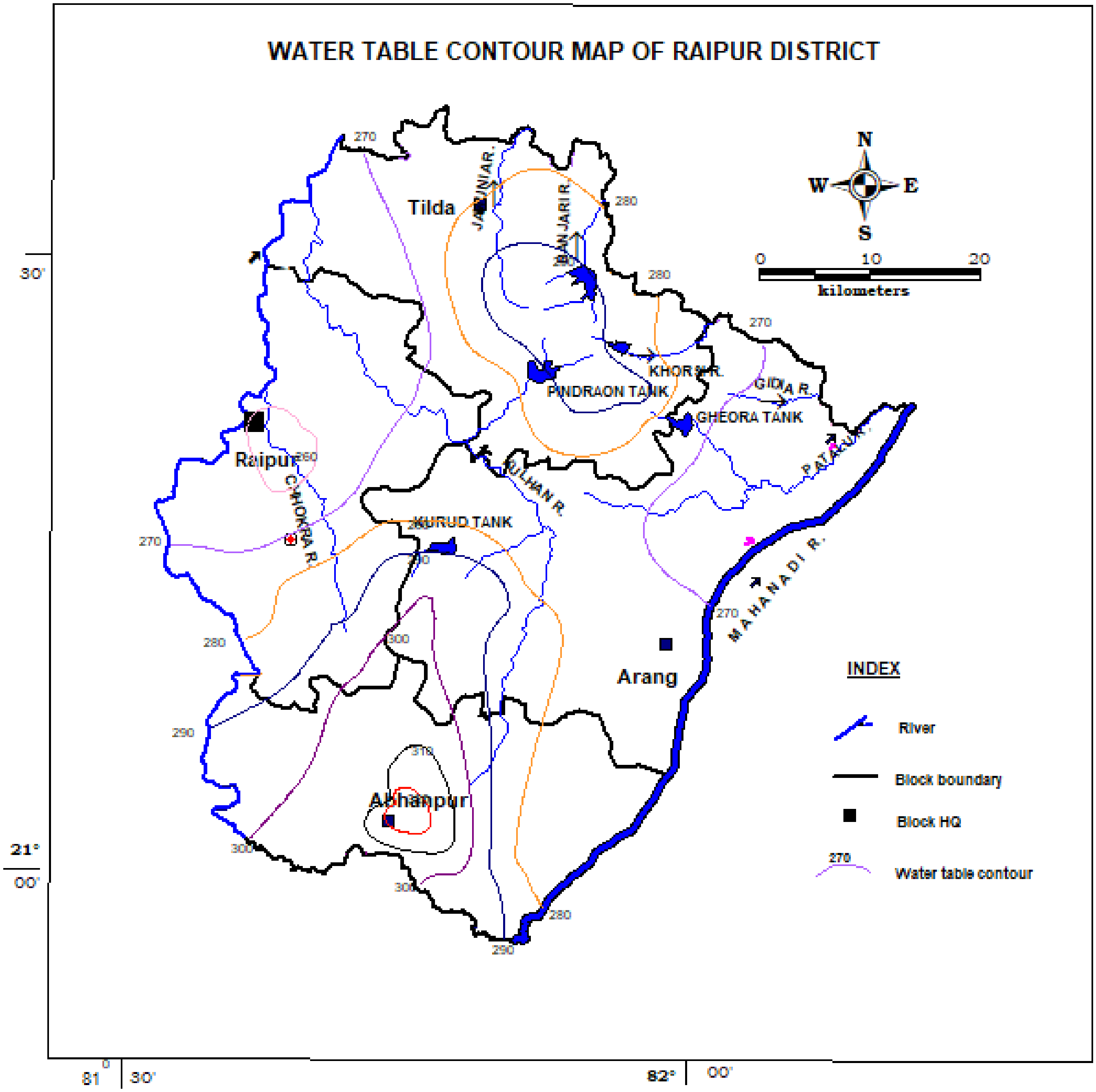
An attempt has been made to assess the Static Ground Water Resources Raipur district which is the resource that remains available below the dynamic zone of water table fluctuation. This is not replenished every year and extracting this water is ground water mining. The quantum of ground water available for development is usually restricted to long term average recharge or dynamic resources. For sustainable ground water development, it is necessary to restrict it to the dynamic resources. Static or in-storage ground water resources could be considered for development during exigencies that also for drinking water purposes. It is also recommended that no irrigation development schemes based on static or in-storage ground water resources be taken up at this stage.

5.4Ground Water Quality:

Ground water quality of shallow aquifer as well as deeper aquifer in Raipur district for drinking,irrigation and industrial purposes is assessed on the basis of analysis of ground water samples were carried out from 38 nos. of observation wells for shallow aquifer &33 exploratory wells for deeper aquifer (**Annexure-IIIA & B**). Apart from these, 40 nos. of water samples were also analysedto assess the arsenic and uranium contamination respectively.

5.4.1Drinking water quality:The concentrations of various parameters for both shallow & deeper aquifers are presented in the table5.6.

Map-5.4: Ground water table map of Raipur district, Chhatisgarh



Map-5.5: Ground water resource map of Raipur district, Chhatisgarh

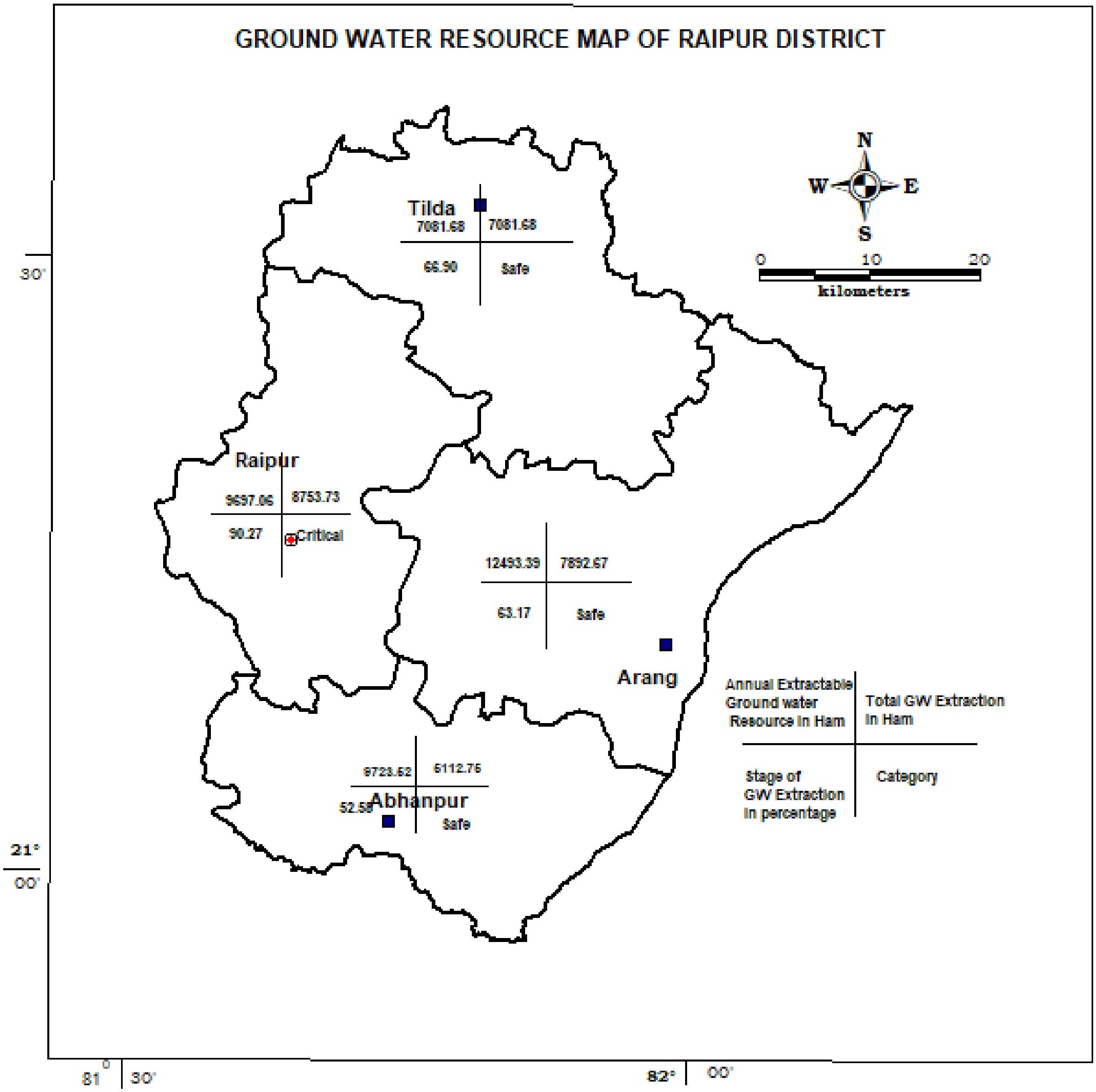


Table-5.6:Ground water quality data for shallow & deeper aquiferoin Raipur district

Sl. No	Parameters (in ppm)	Shallow Aquifer			Deeper Aquifer			Remarks
		Min	Max	Avg	Min	Max	Avg	
1	pH	7.44	8.32	7.86	7	9.3	7.79	Alkaline in nature
2	EC(in µS/cm at 25° C)	108	2345	854.63	91	1541	498.45	EC is higher side at some places for both shallow and deeper aquifer.
3	HCO_3	61	420.9	239.18	24	311.1	187.52	Shallow aquifer is at higher side of bicarbonate at some places.
4	Cl	3.55	376.3	69.51	3	135	33.84	Beyond permissible limit
5	SO_4	3.7	406	65.84	0	86.42	24.07	Both shallow as well as deeper aquifer are under permissible limit.
6	F	0.03	1.4	0.39	0.07	1.17	0.41	Free from fluoride contamination
7	TH	90	645	273.55	50	560	178.25	Shallow aquifer is hard at some places.
8	Ca	18	222	77.16	2	132	36.88	Ca content is beyond permissible inshallow aquifer at some places
9	Mg	3.6	67.2	19.36	4	47	16.59	Beyond permissible limit
10	Na	2.5	169	54.31	9.2	215	190	Beyond permissible limit
11	K	0.19	98	7.09	1.4	215	74.91	Beyond permissible limit
12	NO_3	0.1	98.4	35.5				Shallow aquifer is nitrate contaminated at many places

The above table-5.8 indicates that the ground water of both shallow and deeper aquifer are alkaline in nature.High concentrations of nitratebeyond the permissible limit were observed at Ghodari, Godhi, Nawagaon, Narra, Piparhatta of Arangblock, Abhanpur,Bajrangpur of Abhanpur block, Biladi,Math of Tilda block andCharauda,Devpuri, Devri, Dharsiwa, Manabasti, Semoriya of Dharsiwablockblock.

Arsenic and Uranium were not observed in ground water of the district. Except few locations where the nitrate concentrations are found beyond the permissible limit, the ground water of Raipur district was found suitable for drinking purposes.

5.4.2Irrigation water quality:To know the suitability of water for irrigation purposes SSP and KI are computed. By obtained value of SAR and EC the US Salinity diagram is plotted in **Fig-5.6 (A&B)**. The following table-5.7 presents the locations of less suitable from irrigation point of view on the basis of SAR, SSP, KI & RSC.

Table-5.7: Area lesssuitablefor shallow aquifer ground water Irrigation

Sl. No.	**Location**	**EC in m μ/cm**	**SAR**	**KI**	**SSP**	**RSC**
1	Bajrangpur	577	3.00	0.56	56.33	1.4
2	Saragaon	749	5.43	0.74	74.09	3.7
3	Baihar	2345	3.06	0.39	38.99	-4.6

SAR-Sodium absorption ratio, SSP- Sodium soluble percentage, KI-Kelly Index, RSC-Residual sodium Carbonate

The SAR, SSP, KI & RSC value indicate that shallow aquifer ground water is suitable for irrigation. SAR value more tha 26 indicates the unsuitability from irrigation point of view due to very high soium water. But none of the sample is above SAR 26 value. However, an attempt has been made to classify the shallow aquifer ground water quality on the basis of WQI (Water Quality Index). The result is presented in table-5.8.

Table-5.8: Classification of ground water quality for irrigation use based on WQI

Sl. No	Location	WQI	Class	Restriction
1	Piparhatta	153.21	II	Slight
2	Palari	316.04	III	Moderate
3	Baihar	343.51	III	Moderate

The above table shows that only 5% sample shows moderate restriction on irrigation and 1% show slightely restriction on irrigation. Hence overall it may be concluded that the ground water from shallow aquifer is suitable for irrigation purposes.However careful study may be done for irrigation in above areas as mentioned in above three tables.

5.4.3Industrial water quality:The corrosivity ratio is the susceptibility of groundwater to corrosion. It is expressed as ratio of alkaline earths to saline salts in ground water. The corrosivity ratio is defined by the formula, ((Cl/35.5) + 2(SO4)/96)/(2 (HCO3+CO3)/ 100) (Rosalin Das etal,DRS.splpubl pp.18-28) Where all the ions are expressed in ppm of groundwater. It has been found that 79 % water samples have corrosive ratio (CR) less than one (safe zone), while 21% of samples have (CR) more than one (unsafe zone) (Table 5.9). In the area, where groundwater has Corrosive Ratio (CR) value more than 1, Polyvinyl Chloride (PVC) pipes should be used. I

Table-5.9: Classification of ground water quality for industrial purpose use based on CR

Corrosivity Ratio (CR)	**Water Category**	**Percentage of water Samples**	**Locations**
<1	Safe Zone	79	
>1	Unsafe Zone	21	Umaria station, Chrauda, Devpuri, Dumartarai, Narra, Piparhatta, Baihar, Dharsiwa

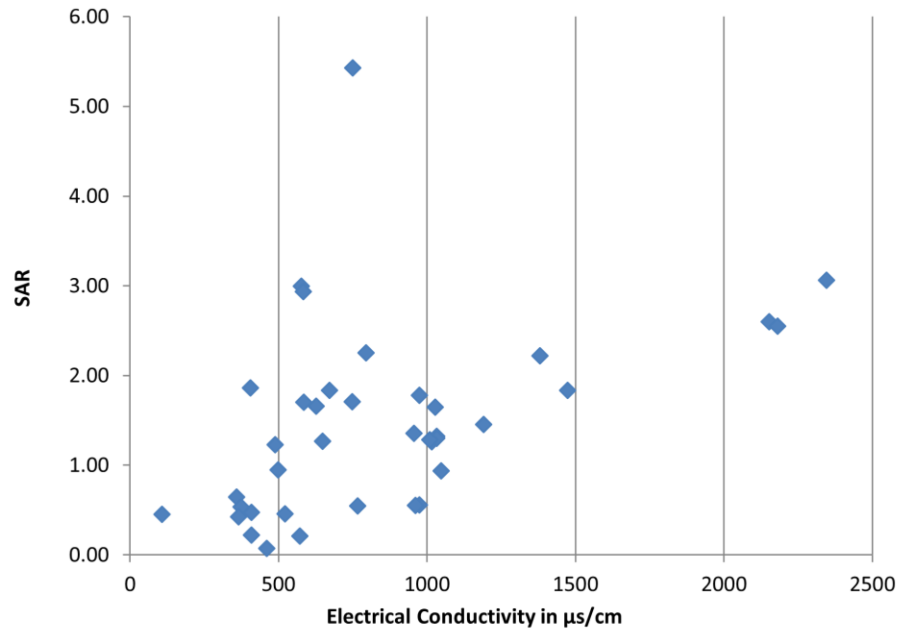


Fig-US Salinity Plot for Shallow Aquifer in Raipur District

Map-5.6: US salinity plot for shallow aquifer of Raipur district, Chhatisgarh

5.4.4 Arsenic contamination: No arsenic contamination in ground water is found in any ground water sample collected in Raipur district.

5.4.5 Uranium contamination: The maximum uranium content in ground water is found at Baihar, Arangblock which is about 0.0034 mg/l. There are also traces of uranium found at some locations in Arang block namely at Narra(0.003 mg/l), Piparhatta (0.0031 mg/l). Since according to BIS the maximum permissible limit of Uranium is 0.03 mg/l (as per WHO provisional guidelines), the ground water in Raipur district is safe from Uranium contamination point of view.

5.4.6 Type of Ground Water:The piper diagram (**Fig-5.7(A&B**) indicates that the ground water of shallow aquifer of Raipurdistrict is mostly characterized by calcium-bicarbonate (Ca-HCO3) type. However mixed type i.e. (Ca+Mg) &(SO4+Cl) type ground water also observed at spome places. The deeper aquifer is characterized by Na-K-bicarbonate type (Na,K-HCO3) type.

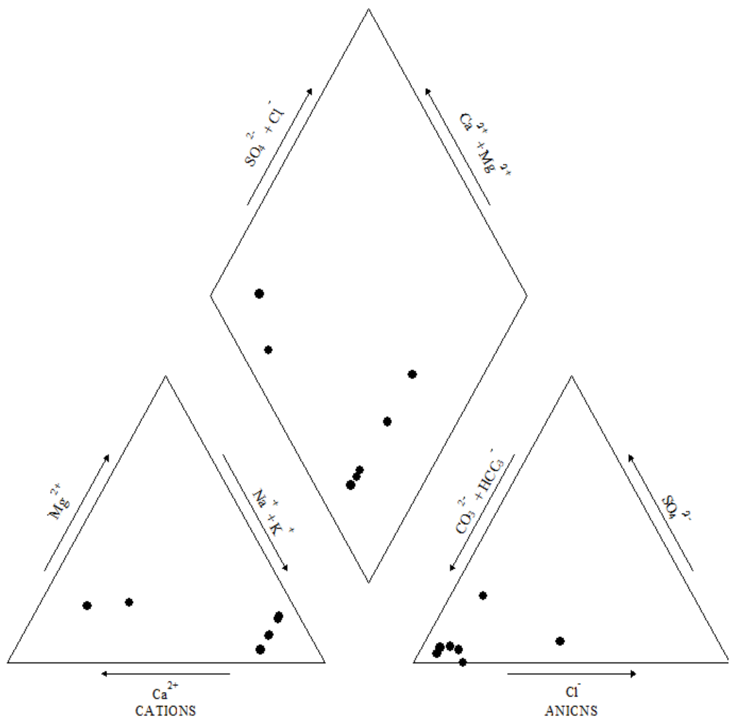


Fig.5.7 A: Piper diagram for Deeper Aquifer in Raipur district, Chhattisgarh

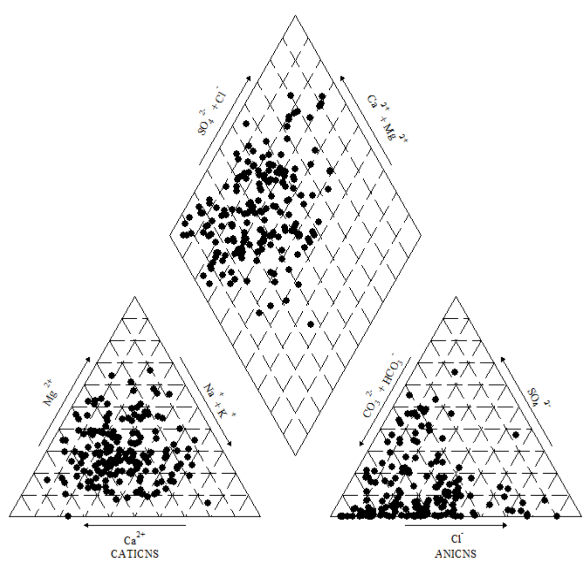


Fig.5.7 B: Piper diagram for Shallow Aquifer in Raipur district, Chhattisgarh

AQUIFER MAPPING & MANAGEMENT PLAN

6.1 Ground Water related issues & problems:

1. Due to large scale pumping from Chandi and Gunderdih Formation for irrigation, the water level in this formation goes deep in summer and the sustainability of shallow hand pumps are threatened.
2. There is no spacing criteria for the drilling of bore well leading to the exploitation of groundwater resources.
3. At many locations nitrate concentrations are found beyond the permissible limit.
4. High stage of groundwater development, inherent character of aquifer giving low yield, growing water consuming crops in spite of critical stage of development and declining of water level are the major ground water issues in the district.

6.2 Status of Aquifer Mapping & Salient findings:

All the four blocks of Raipur districthave been covered under aquifer mapping. The salient features of the aquifer mapping & management plan for Raipur district may be summarized as follows: - as follows:

The district is underlain mainly by the geological formations ranging in age from Meso to Neo Proterozoic. The Raipur group of rocks of Chhattisgarh super group occupies major parts of the district comprising of limestone and shale. The major aquifer groups in the block are i) Chandi Limestone, (ii) Gunderdihshaleand(iii) CharmuriaLimestone. There are four types of aquifers in the block which are Aquifer-I (depth upto 25m): Weathered Formation, Aquifer- II (depth upto 25-200m): Fractured Chandi Limestone, Aquifer- III (depth upto 25-200 m): FracturedGunderdih Shale, Aquifer- IV (depth upto 25-200m): Fractured Charmuria Limestone. Ground water occurs in phreatic condition in the weathered mantle of these rocks, which extends up to a depth of 25 mbgl. The caverns formed in limestone and dolomites holds good amount of ground water which are limited mostly to around 90 meters. Limestone and dolomite form the main aquifer system in the area. Charmuria limestone is not very good yielding. Cavernous limestone of Chandi formation forms the good aquifer in the district. The alluvium blanket along the major rivers also forms good repository of ground water. The yield of the wells drilled by CGWB in Chhattigarh formation varies from 0.2 to 13.14 Ips. The transmissivity of this formation ranges from 2.1 to 121.7 m2/day and the specific capacity ranges between 51.5 to 403lpm/m of draw down and storativity ranges from 0.0014 to 0.0032. The transmissivity value of Chandi Formation varies from 2.1 to 121.7 m2/day where Gunderdehi Formation has transmissivity values ranging from 6.02 to 55.87 m2/day. One to two sets of potential fracture zone lie within 100 m depth. High stage of groundwater development, inherent character of aquifer giving low yield, growing water consuming crops despite critical stage of development, and declining of water level are the major ground water issues in the district. The long-term ground water level trend indicates that there is appreciable change in water level at some places both in pre-monsoon and post monsoon period. The Annual Extractable Ground Water Resources as per GWRE 2020 in the district is 42499.6ham with maximum of 12493.39 ham in Arangblock and stage of ground water extraction is 68.23% with maximum of 90.27 % in Dharsiwa block which is under critical category. In a long-term sustainable basis, we must go for artificial recharge, particularly to recharge the area of deeper water level by construction of Percolation Tank (381), Nala bund & Check dam (1285), Recharge shafts (3081) and gully plug/gabion structures (2296) to recharge 167.12 mcm water to underground.

6.3 Status of Ground Water Development Plan:

The ground water development in the district is being done by dug wells and tube well/ bore wells. The dug well depth varies from 5 to 20 m and the diameter varies from 1 to 4 m. The bore wells drilled in the area are 60 to 150 m deep with diameter of 100 to 150 mm. Diesel or electric operated pumps of 1 to 5 HP or traditional tenda is used to lift the water from dug wells for irrigation purposes. The submersible electrical pumps of 3 to 5 HP are used for irrigation purpose in case of bore wells in the area. The bore wells in the area can irrigate an area of 0.5 to 2.5 ha for paddy.

The stage of ground water development estimated for Dharsiwa block is 90.27 %, for Arang block is 63.17 %, for Tilda block is 66.9% and for Abhanpur block is 52.58%.The overall stage of development in Raipur district is 68.23%. The block wise stage of ground water extraction map in the district is depicted in **Map-5.5**.The details of artificial recharge structures to enhance ground water resource and nos. of irrigation tube wells or irrigation dug wells or combination of both that can be constructed at suitable locations in the district for more ground water development and to create more irrigation potentialare presented in the table-6.1(A)& table 6.2 (B) respectively.

Table-6.1 (A): Details of AR structures in Raipur district

Block	**Percolation tank recharge capacity 0.2192 mcm**	**Nalas bunding cement plug/ check dam recharge capacity 0.0326 mcm**	**Recharge shaft recharge capacity 0.00816mcm**	**Gully plugs Gabbion structures recharge capacity 0.0073 mcm**	**Total recharge in mcm**
Dharsiwa	130	438	1050	782	56.99
Arang	40	135	324	242	17.56
Tilda	182	613	1469	1095	79.77
Abhanpur	29	99	238	177	12.80
Total	***381***	***1285***	***3081***	***2296***	***167.12***

Table-6.1 (B): Details of irrigation tube wells and dug wellsto be constructed in Raipur district

Block	Stage of ground water extraction (%)	Number of TW Recommended in each block (Assuming unit draft as 1.6 ham/structure/year)	Number of DW Recommended (Assuming unit draft as 0.72 ham/structure/year)	Irrigation potential likely to be created for paddy (Ha)	Irrigation potential likely to be created for wheat, Ground Nut, Sunflower (Ha)	Irrigation potential likely to be created for Mustard &Pulses (Ha)
Dharsiwa	90.27	-	-	-	-	-
Arang	63.17	-	-	-	-	-
Tilda	66.9	-	-	-	-	-
Abhanpur	52.58	451	1002	801.6	1803.6	2404.8
Total		***451***	***1002***	***801.6***	***1803.6***	***2404.8***

Taking crop water requirement of Paddy as 90cm, wheat, groundnut &Sun flower as 40cm and Pulses & Mustard as 30cm

From the table 6.1(A), it is depicted that 381 nos. of percolation tank, 1285 nos. of nala bunding/cement plug/check dams, 3081 nos. of recharge shafts and 2296 nos. of gully plug/gabion structures may be constructed at suitable locations that can enhance the ground water source to 167.12 mcm more.

Similarly, from the table 6.1(B), it is depicted that 451 nos of irrigation tube wells or 1002nos of irrigation dug wells or combination of these two may be constructed in the district that to restricted to Abhanpur block only that can likely to create an irrigation potential of 801.6 ha for paddy, 1803.6 ha for wheat, Ground Nut, Sunflower and 2404.8 ha for Mustard & Pulses respectively. Ground water development structures are to be constructed only in Abhanpur block because other blocks have stage of ground water extraction more than 60%.

6.4 Aquifer Map:

Finally based on above studies such as the aquifer characteristic of various aquifer groups&ground water level behavior in various seasons, the following maps for Raipur district were prepared:

(i) Aquifer map 3-dimesional (**Map-6.1**)

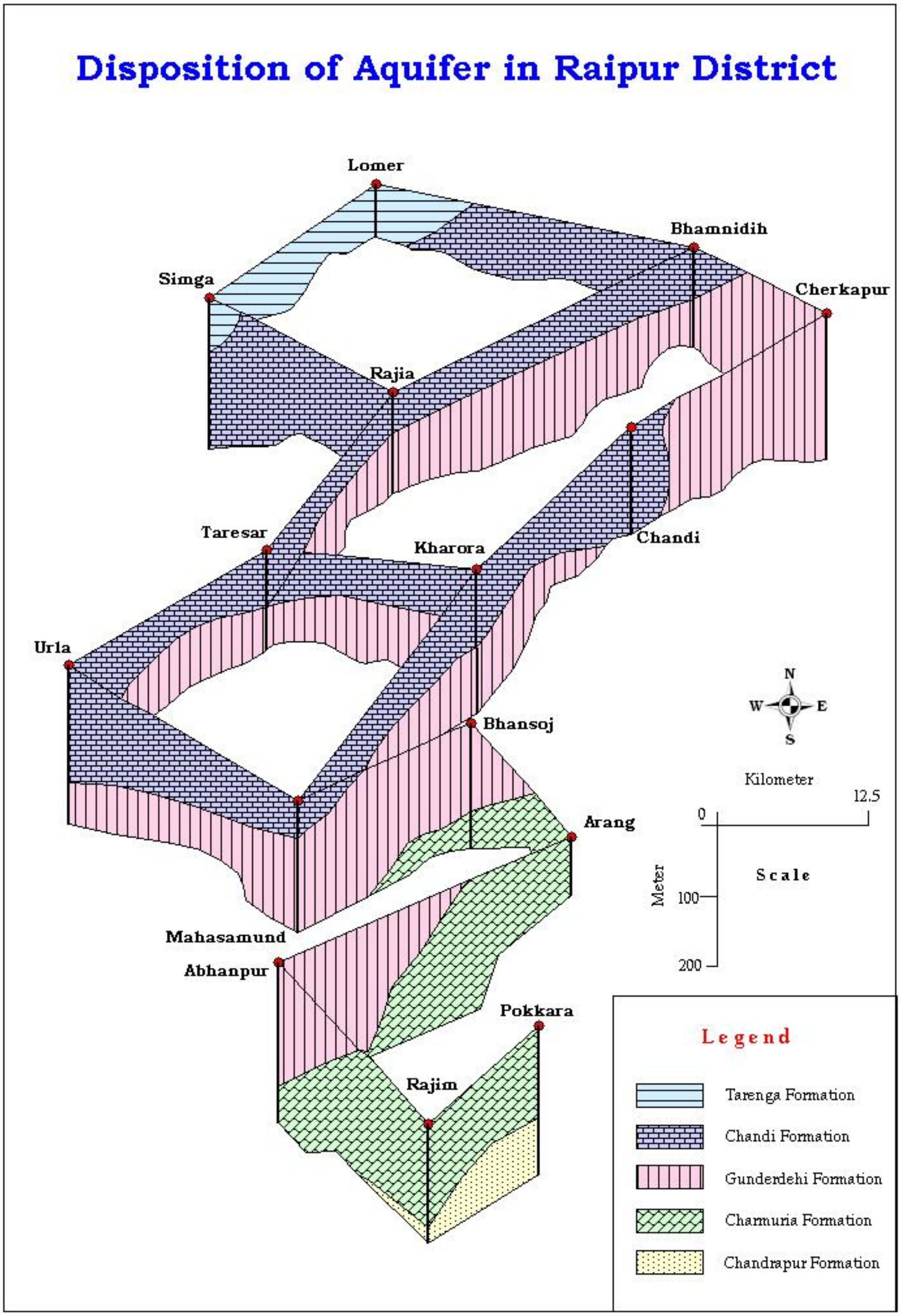
(ii) Aquifer map 2-dimensionsl, (**Map-6.2 A & B)**

(iii) Hydrogeological map of Raigarh district (**Map-6.3)**

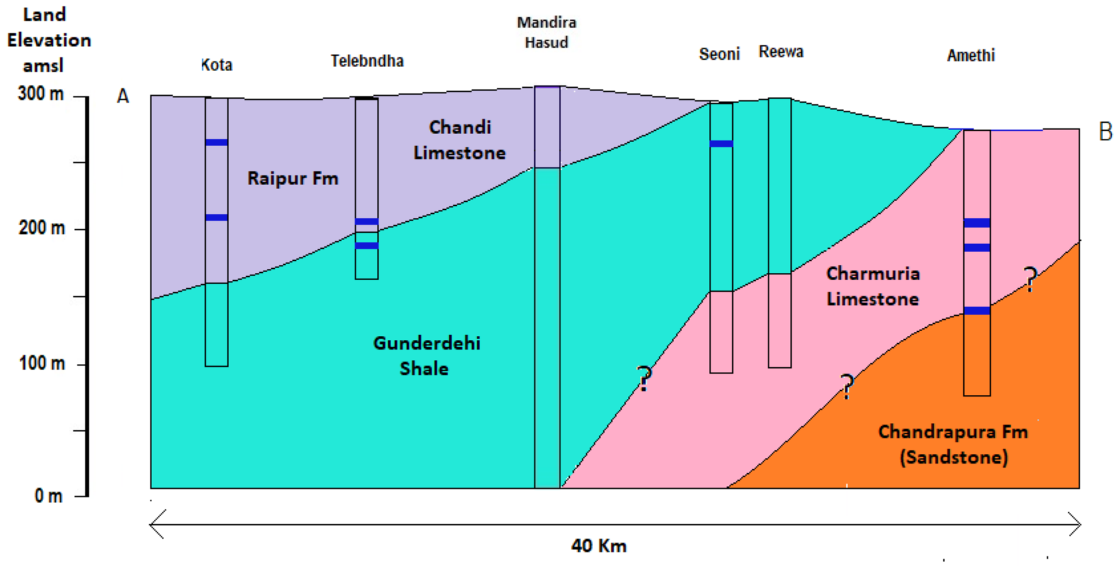
(iv) The yield potential map based on the exploration (**Map-6.4)**

(v) Ground water development potential & Artificial recharge Prospect (**Map-6.5)**

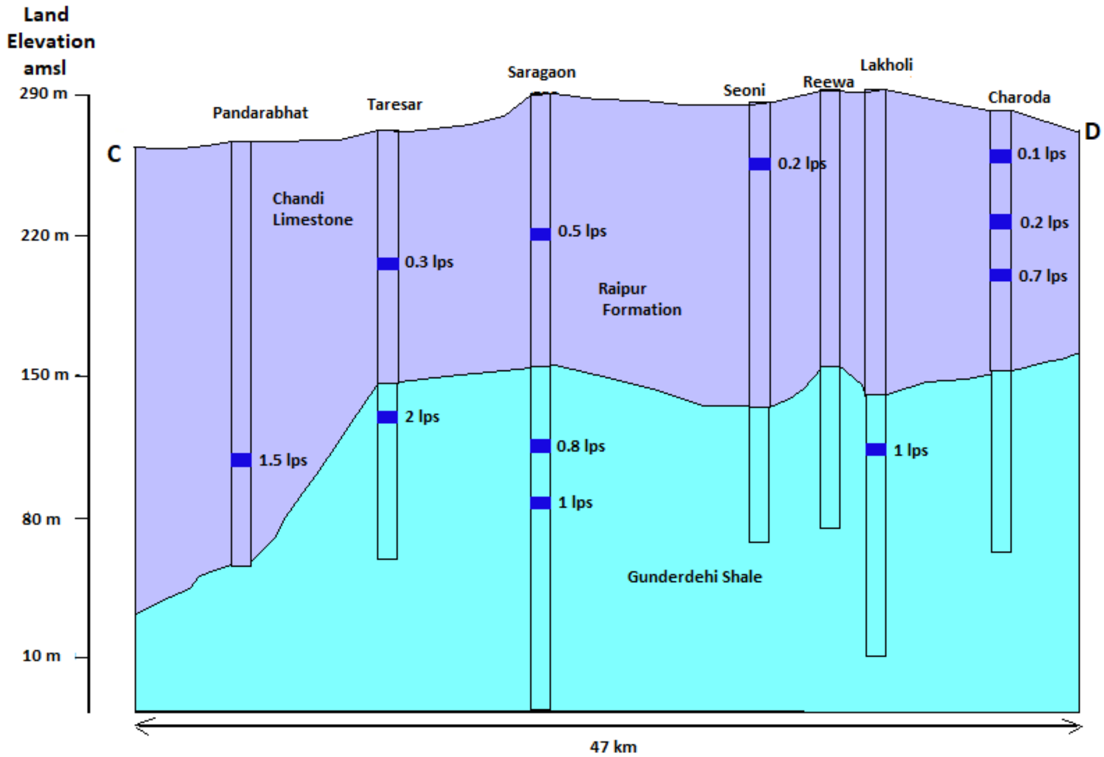
Map-6.1: 3-Dimensional Disposition of Aquifer in Raipur district, Chhattisgarh

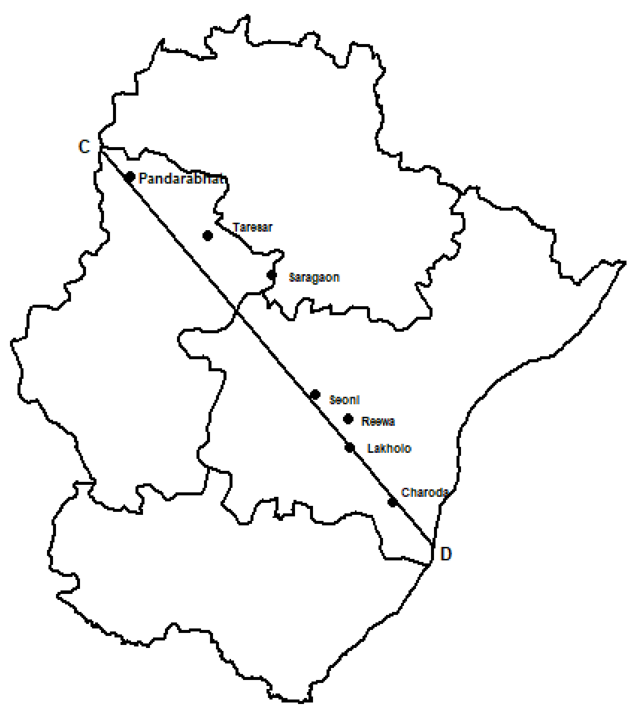


Map-6.2 A: 2-Dimensional Disposition of Aquifer in Raipur district, Chhattisgarh in EW direction

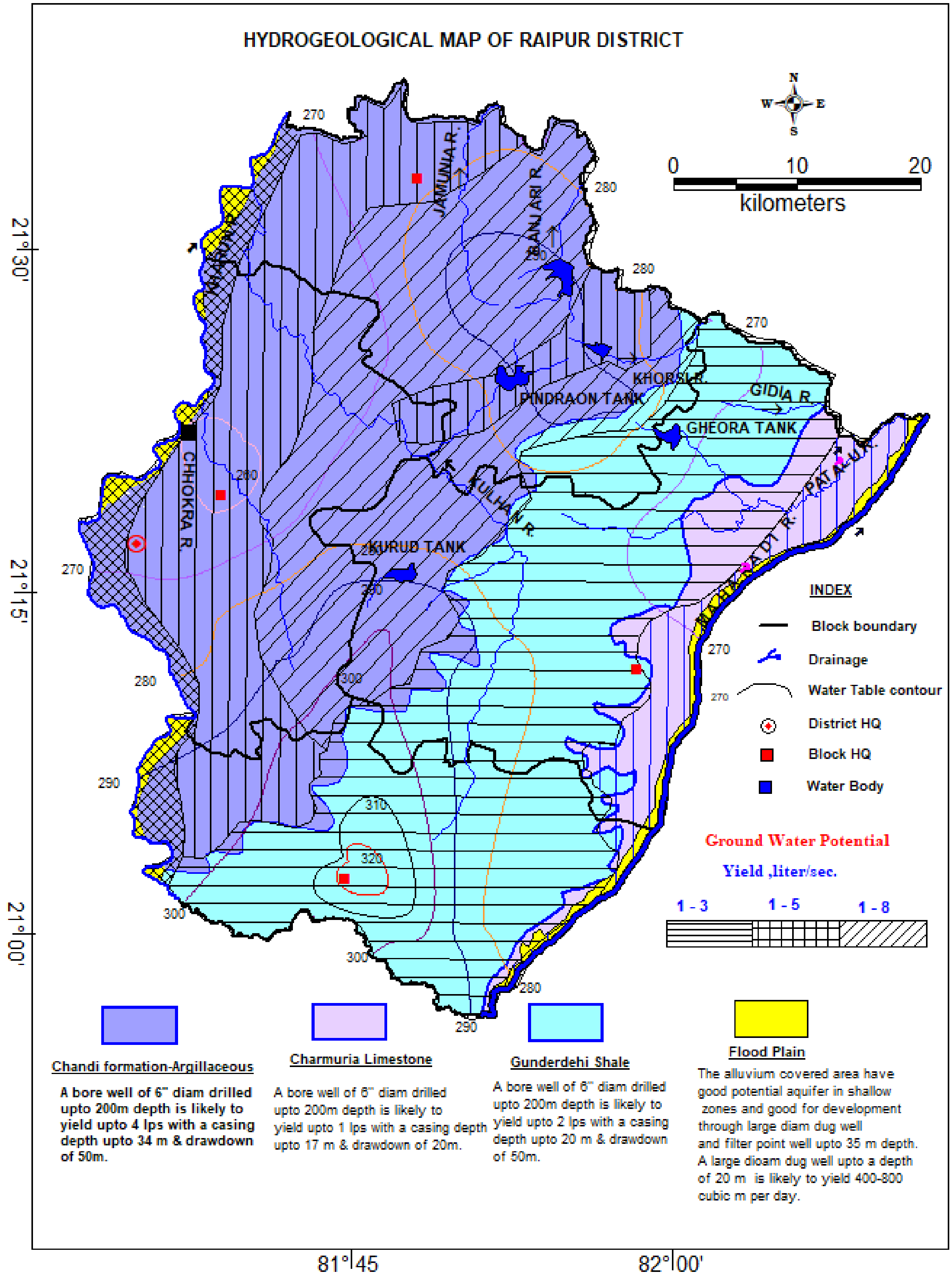


Map-6.2 B: 2-Dimensional Disposition of Aquifer in Raipur district, Chhattisgarh in NW-SE direction

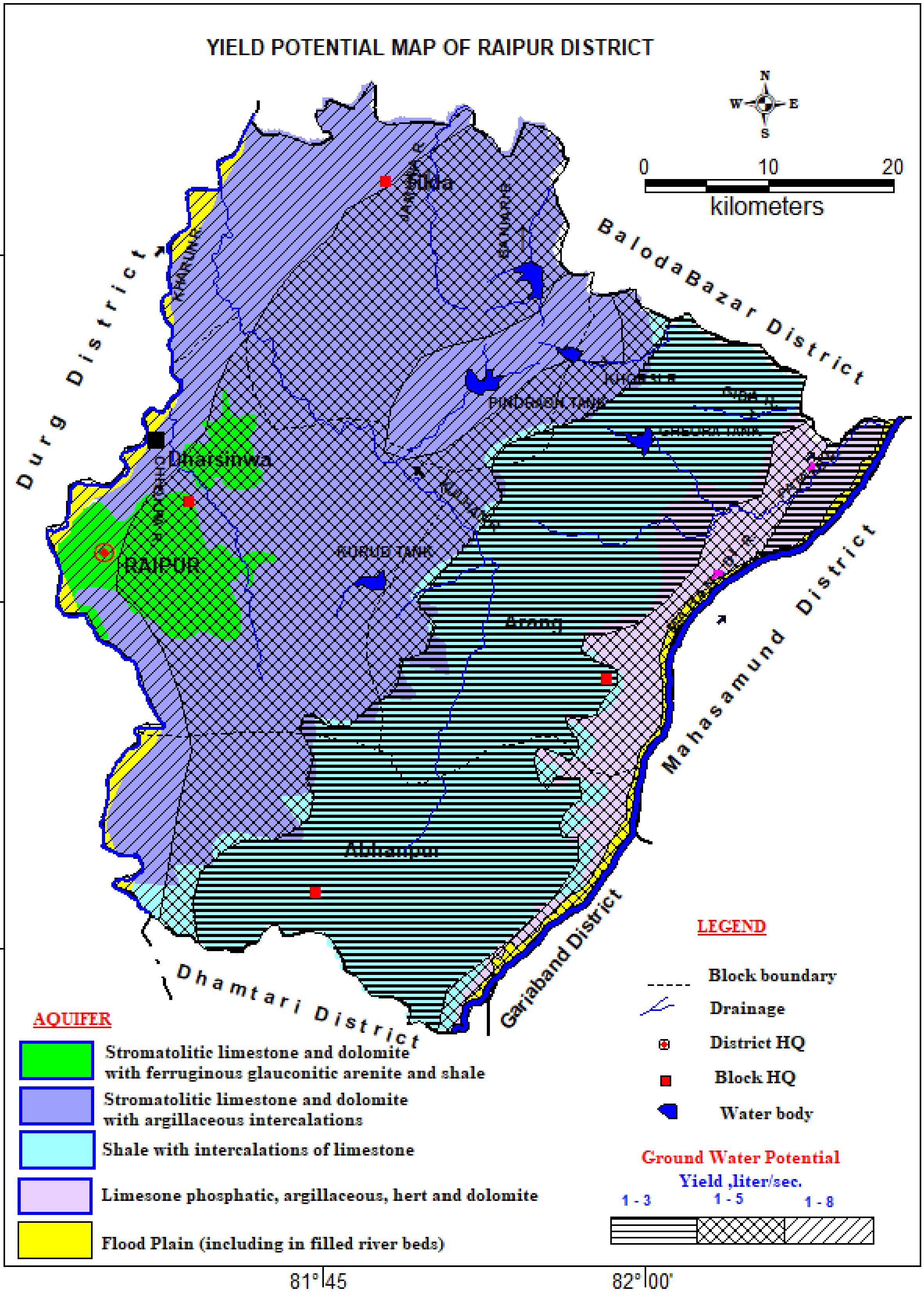




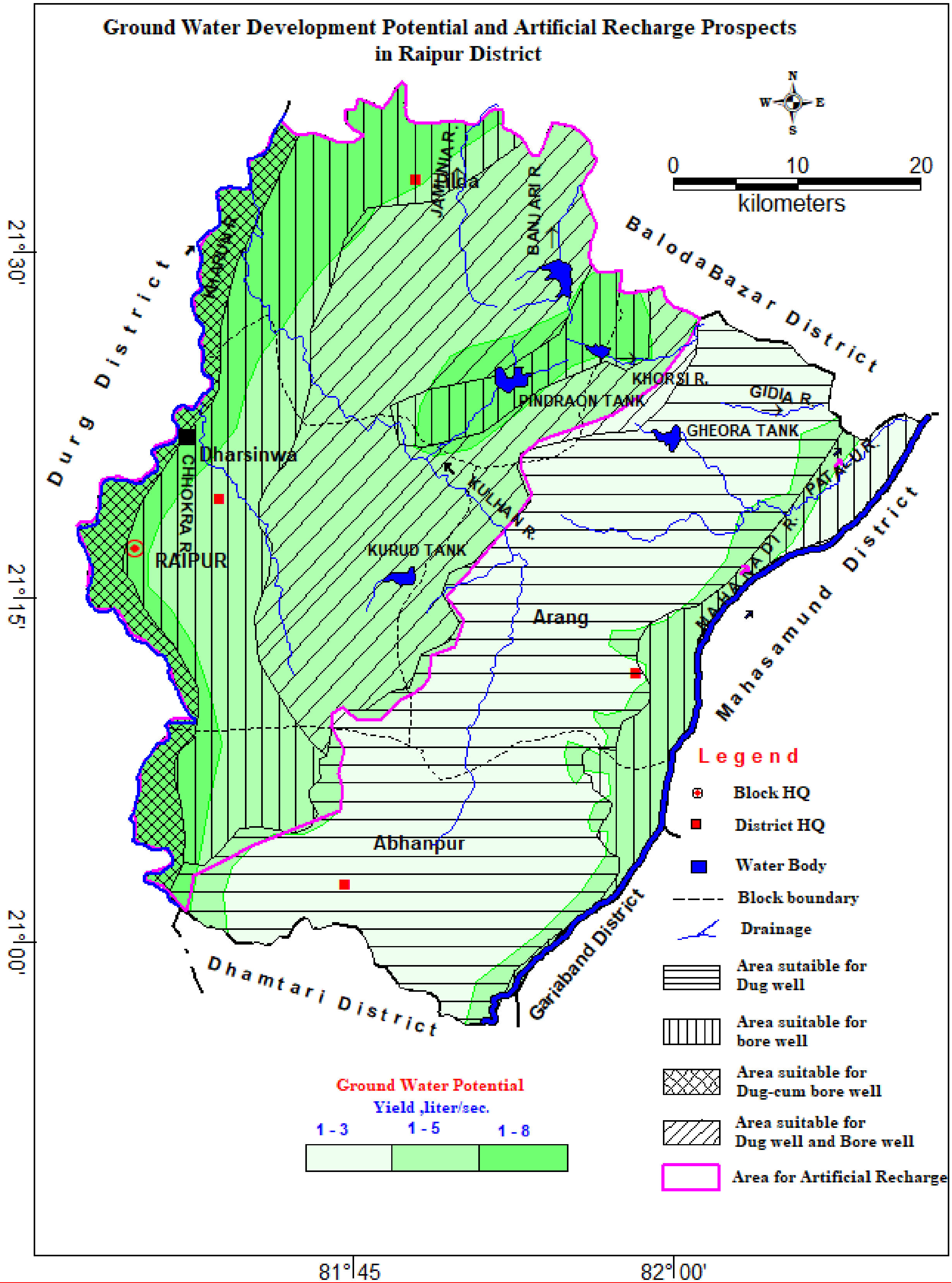
Map-6.3: Hydrogeological map of Raipur district, Chhattisgarh



Map-6.4: Yield potential map of Aquifer in Raipur district, Chhattisgarh



Map-6.5: Ground water Development Potential & Artificial Recharge Prospects map of Raipur district, Chhattisgarh



GEOPHYSICAL STUDIES

Geophysical (1D Profiling Survey) investigations were carried out Naya Raipur area, Raipur District of Chhattisgarh State. The investigation includes 1D Gradient &Wenner Profiling followed by vertical electrical soundings at different spots to locate the site having maximum thickness of potential ground water bearing zone (considering series of fractures). 3 nos. GRP & 1 no. Wenner Profiling were possible to conduct with maximum current electrode separation C1C2 = 300 mt. at the above mentioned area.

The present study has been carried out at in Naya Raipur area, Raipur District, Chhattisgarh. The site is located about 9 km south east of Raipur city on Lalpur- Dhamtari road situated between Latitude: N 21° 12’12” & 21° 12’21”Longitude: E 81°40’03” & 81°40’11”under Survey of India (SOI) Topo Sheet no. 64G/11. Present study area covers

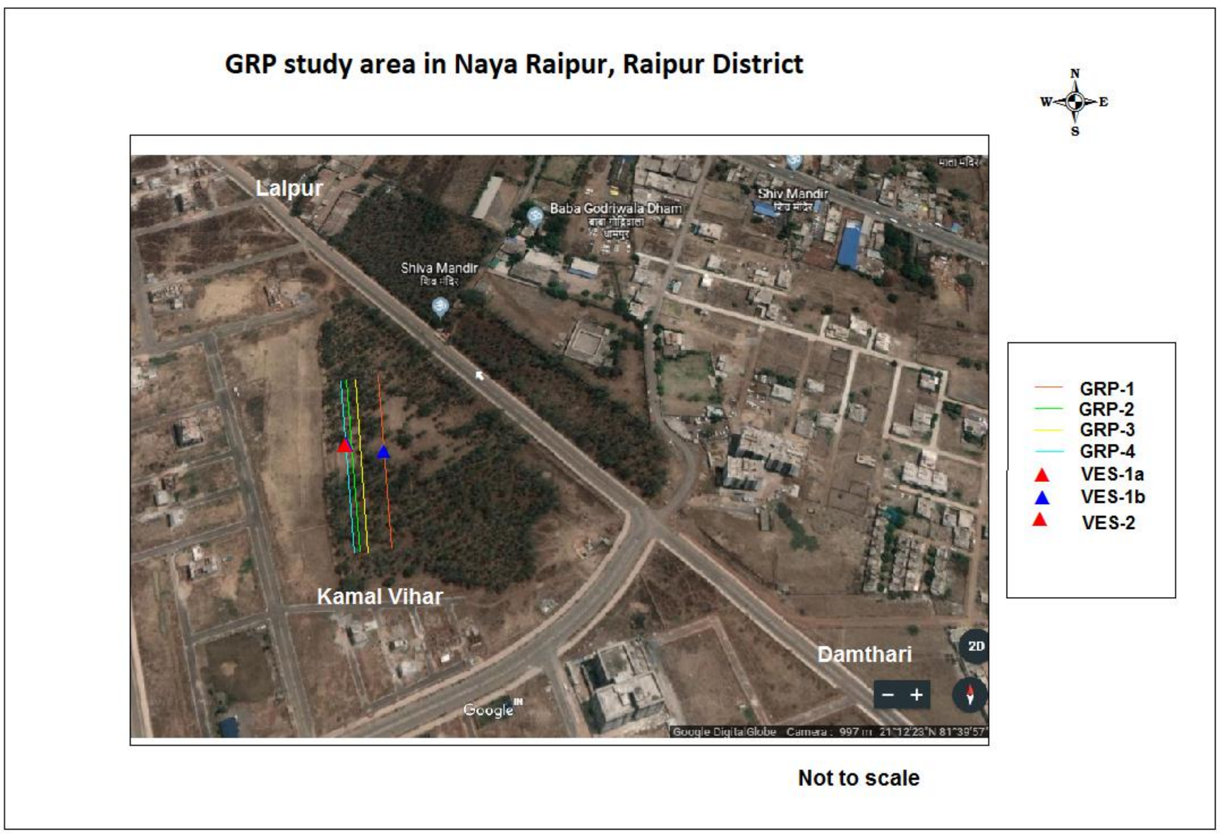


Figure-7.1: Location map of the study area

To assess the groundwater potentiality at Naya Raipur area, Raipur District, Chhattisgarh. A total five profiling (One Wenner and four Gradient Resistivity Profiling) were carried out to decipher the sub surface hydrogeological conditions beneath the area to locate suitable sites for bore well drilling. The maximum current electrode spreads for conducting Wenner and Gradient Resistivity Profiling was carried out over a spread of 300 m (AB).

Top soil thickness 2 to 2.2 m, weathered layer thickness is maximum 13m and resistivity varies from 30-150 Ohm-m. The fractured rock resistivity varies from 225-300 Ohm-m and fracture formation depths vary 4-9m (shallow fractures). Some deeper fractures may be at 60 -85m. The hard and compact formations resistivity varies from 747-871 Ohm-m.

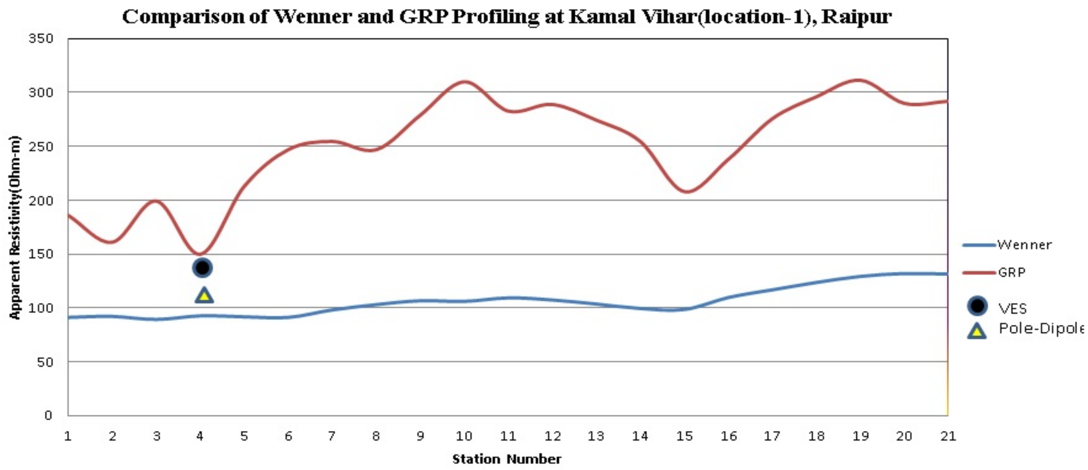
7.1 Resistivity Survey

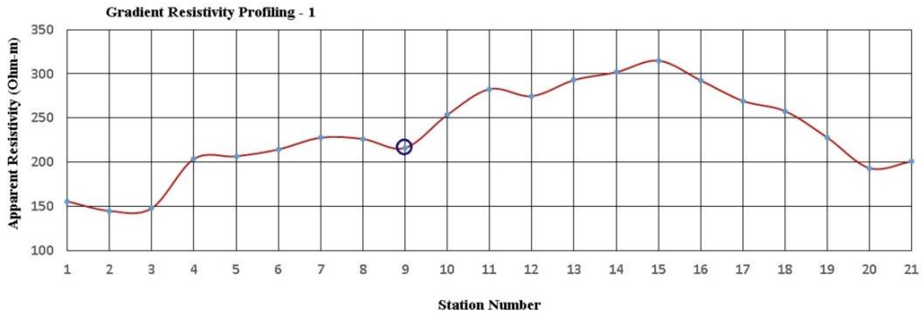
Using Ohm's law electrical resistivity of sub-surface geologic formation is determined through artificially energizing the subsurface and carrying measurements on the ground surface. Contrast in resistivity value of an individual layer with the surrounding or effective presence (dependent of its relative resistivity and thickness) makes it detectable.

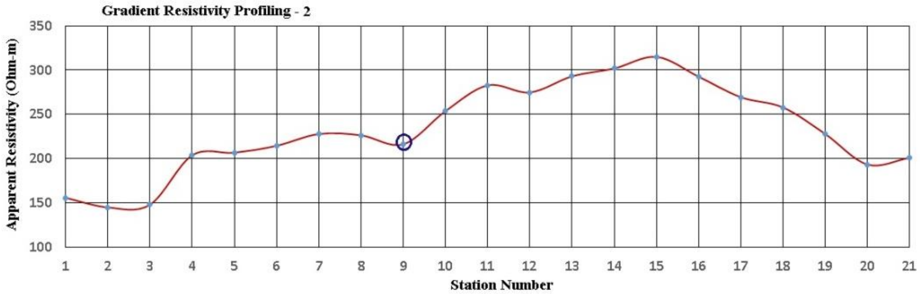
Gradient Resistivity Profiling (GRP) was carried out at Raipur District. To get the desired information about the prevailing hydrogeological conditions beneath the study area, the maximum current electrode (AB) spacing for VES were kept 240 m. The VES curves obtained from the area are mostly HA type in nature, which indicate the similar variation in subsurface hydrogeological conditions.

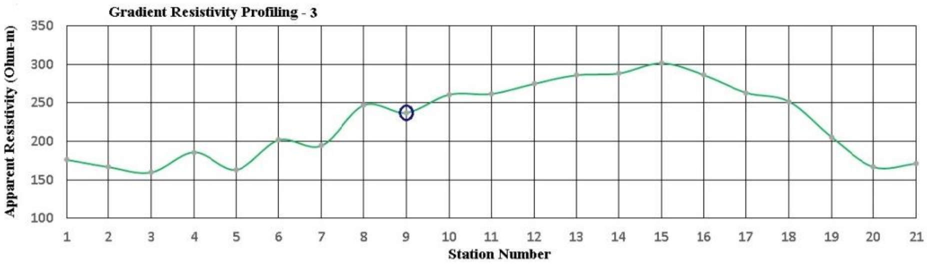
From the interpretation of resistivity survey the following conclusion was deciphered. The topsoil resistivity varies from 141-150 Ohm-m. Weathered layer resistivity value varies in the order of 20.9-30 Ohm-m whereas the Sub weathered formation resistivity values are in the range of 154-300 Ohm-m. The Hard rock formation resistivity varies from 747-871 Ohm-m. The thickness of Top soil varies from 2.0m to2.2m weathered layer thickness varies from 9m to 11m and the thickness of 4m to 9m. The thickness for the last layer is assumed as infinite.

The Gradient Resistivity Profiles data have been plotted on linear graphs and shown in figure 2 to figure 3. The observed data over profiles have been interpreted qualitatively in term of resistivity `low' and `high'. The observed apparent resistivity over GRP vary from 89 to 280 Ohm-m. The Wenner and Gradient Resistivity Profiling data of the study area is given in Annexure-III.


Comparison of Wenner and GRP Profiling at Kamal Vihar(location-1), Raipur
Apparent Resistivity(Ohm-m)
Station Number
Wenner
GRP
VES
Pole-Dipole


Gradient Resistivity Profiling - 1
Apparent Resistivity (Ohm-m)
Station Number


Gradient Resistivity Profiling - 2
Apparent Resistivity (Ohm-m)
Station Number


Gradient Resistivity Profiling - 3
Apparent Resistivity (Ohm-m)
Station Number

7.2 TEM Data Processing & Interpretation:

82 nos. TEM in Naya Raipur, Raipur district covering 184 sq km area of Chhattisgarh state under NAQUIM Programme have also been carried out during the year 2019-2020. All the TEM data were processed through Terra TEM Plot software from *.BIN extension file to *.TEM extension file and further to *.USF extension file. The TEM data interpretation were done through IX1D software as provided with the instrument by importing the TEM data *.USF extension file.

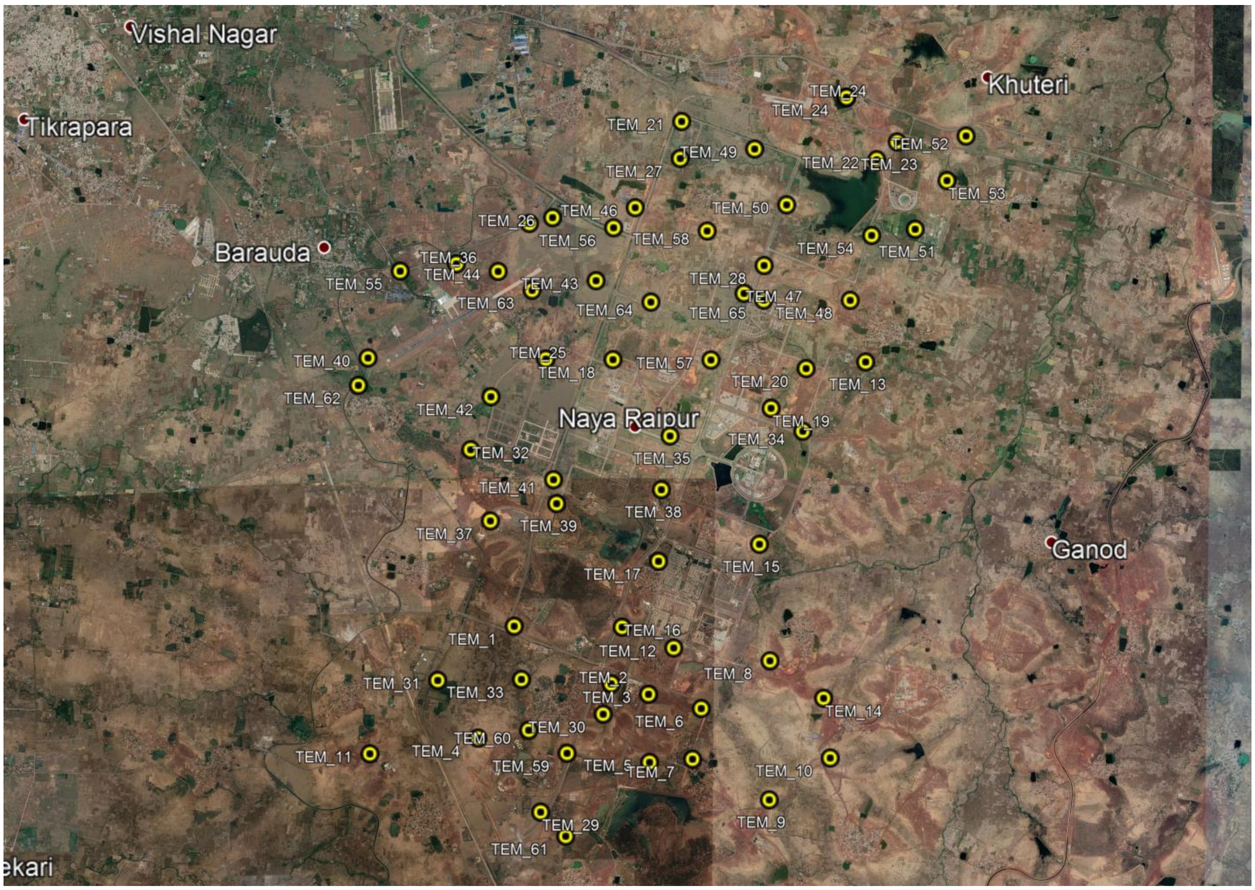


Fig.7.1: Study Area of Surface GeophysicalInvestigation (TEM) of RaipurDistrict

7.3 Conclusions

Wenner, Gradient Profiling has narrow down the low resistivity point in the study area and in that low resistivity point we have carried out the Vertical Electrical Sounding (VES) survey. On the basis of VES data interpretation results in the study area the topsoil resistivity varies from 141-150 Ohm-m. Weathered layer resistivity value varies in the order of 20.9-30 Ohm-m whereas the fractured formation resistivity values are in the range of 154-300 Ohm-m. The Hard rock formation resistivity varies from 747-871 Ohm-m.

The thickness of Top soil varies from 2.0m to2.2m weathered layer thickness varies from 9m to 11m and the thickness of 4m to 9m. The thickness for the last layer is assumed as infinite.

From factor analysis it is observed that there are shallow and deep fractures. Shallow fracture depth varies from 12-16mand deep fracture depth varies from 60 -85m.

From the interpreted results of Naya Raipur (Atal Nagar) area, Raipur District, Chhattisgarh four no. layers have been identified in the 184 sq km study area. The 1st layer identified as top soil with a resistivity ranges from 2.0 ohm-m to 1265.0 ohm-m and thickness varied from 0.8 mt to 3.2 mt.which indicates clayey variety to gravelly variety in nature. The 2nd layer identified as weathered formation with a resistivity ranges from 3.5 ohm-m to 228.0 ohm and thickness varied from 1.4 mt to 4.90 mt..The 3rd layer identified as fractured limestone/shale formation with a resistivity ranges less than 200 ohm-m. The last layer is identified compact limestone/shale formation.

SUM UP

1. The district is mainly covered by rocks of Meso to Neo Proterozoic age, with some isolated pockets of Recent to Sub-recent alluviumcomprising crystalline and metamorphic and consolidated sedimentary rocks of Chhattisgarh Super group

2. The Chhattisgarh super group of rocks occupies major parts of the district comprising of Shale and limestone. The major aquifer groups in the block are i) Gunderdih shale, (ii) Charmuria Limestone (iii) Chandi Limestone and (iv) Quaternary alluvium.

3. There are four types of aquifers in the block which are Aquifer-I (depth upto 25m) Weathered Formation, Aquifer- II (depth upto 25-200m) Fractured Gunderdih Shale, Aquifer- III (depth upto 25-200 m) Fractured Charmuria Limestone, Aquifer- IV (depth upto 25-200m) Fractured Chandi Limestone.

4. Hard rock mainly consist of limestone, shale, dolomite and sandstone belong to Chhattisgarh Supergroup of Proterozoic age. Ground water occurs in phreatic condition in the weathered mantle of these rocks, which extends up to a depth of 25 mbgl. The caverns formed in limestone and dolomites holds good amount of ground water which are limited mostly to around 80 meters. Limestone and dolomite form the main aquifer system in the area. Charmuria limestone and Gunderdehi shale are not very good yielding. Cavernous limestone of Chandi formation forms the good aquifer in the district.

5. The alluvium blanket along the major rivers also form good repository of ground water. The yield of the wells drilled by CGWB in Chhattigarh formation varies from 0.5 to 13 Ips. The transmissivity of this formation ranges from 1.00 to 450 m^2/day and the specific capacity ranges between 2 and 20 Ipm/m of draw down and storativity ranges from 0.003 to 0.000224. The transmissivity value of Chandi Formation varies from 2.2 to 110m^2/day whereas the limestone and shale of Charmuria and Gundedehi formations have very low transmissivity values varying between 1 and 2.5m^2/day.

6. High stage of groundwater development, inherent character of aquifer giving low yield, growing water consuming crops in spite of critical stage of development and declining of water level are the major ground water issues in the district. The long term ground water level trend indicates that there is appreciable change in water level at some places both in pre-monsoon and post monsoon period.

7. The Annual Extractable Ground Water Resources as per GWRE 2020 in the district is 42499.6 ham with maximum of 12493.39 ham in Arang Block and stage of ground water extraction is 68.23 % with maximum of 90.27 % in Dharsiwa block which is under critical category. In a long term sustainable basis, we have to go for artificial recharge, particularly to recharge the area of deeper water level by construction of Percolation Tank (381), Nala bund & Check dam (1285), Recharge shafts (3081) and gully plug/gabion structures (2296) to recharge 167.12 mcm water to underground.

8. Geophysicl studies in Kamal vihar area in the out skirt of Raipur city in Dharsiwa block indicates that the thickness of top soil varies from 2.0m to2.2m weathered layer thickness varies from 9m to 11m and the thickness of 4m to 9m. The thickness for the last layer is assumed as infinite. From factor analysis it is observed that there are shallow and deep fractures. Shallow fracture depth varies from 12-16mand deep fracture depth varies from 60 -85m.

9. From the interpreted results of Naya Raipur (Atal Nagar) area, Raipur District, Chhattisgarh four no. layers have been identified in the 184 sq km study area. The 1st layer identified as top soil with a resistivity ranges from 2.0 ohm-m to 1265.0 ohm-m and thickness varied from 0.8 mt to 3.2 mt.which indicates clayey variety to gravelly variety in nature. The 2nd layer identified as weathered formation with a resistivity ranges from 3.5 ohm-m to 228.0 ohm and thickness varied from 1.4 mt to 4.90 mt..The 3rd layer identified as fractured limestone/shale formation with a resistivity ranges less than 200 ohm-m. The last layer is identified compact limestone/shale formation.

8.1 RECOMMENDATIONS:

1. The spacing criteria between bore wells particularly in Chandi Formation covering deeper water level area particularly in and around Raipur urban area in Dharsiwa block should be regulated to keep control on the depletion of Ground Water level. More number of purpose build piezometers is needed to monitor behaviour of the aquifer actually in use in the district.

2. The Groundwater potential of Gunderdehi shale and Charmuria Formation of Abhanpur and Arang blocks are presently underutilized. The potential aquifer existing between 150 and 200 m depth has not been tapped so far. Especially designed wells can produce sustainable discharge for irrigation from these zones for the entire cultivable land of these blocks.

3. As there is scope for development in the district, either 451 nos. of irrigation tube wells or 1002 nos. of irrigation dug wells or combination of both tube wells and dug wells can be constructed in the district for more ground water development and to create more irrigation potential.

4. Conjunctive use of water resources like creation of more ponds may be given importance.

5. Due to large scale pumping from Chandi Formation for irrigation, the water level in this formation goes deep in summer and the sustainability of shallow hand pumps are threatened. If the water of irrigation tanks or check dam in deeper water level area of Dharsiwa block can be used effectively for artificial recharge through gravity head recharge well, it can enhance the sustainability of hand pumps (the life line for rural drinking water) in the area. These tanks can provide additional water for delayed recharge to aquifer after monsoon.

6. In supply side management, 381 nos. of Percolation tank,1285nos of Nalas bunding cement plug/ check dam, 3081 nos. of recharge shaft and 2296 nos. of Gully plugs /Gabbion structures may be constructed throughout the district that can recharge 167.12 mcm water to underground.

7. Similarly451nos of irrigation tube wells or 1002nos of irrigation dug wells or combination of these two may be constructed in the district that can likely to create an irrigation potential of ***801.6***ha for paddy, 1803.6 ha for wheat, Ground Nut, Sunflower and 2404.8 ha for Mustard & Pulses respectively.

8. All the unused dug wells may be converted to recharge structures by filling suitable filter material (Layers of equal thicknesses of Sand at the bottom followed by Gravels and then by Pebbles). Presently these dug wells are acting as a source of pollution to ground water due to dumping of domestic waste.

9. The source of nitrate in ground water is mostly anthropogenic. Hence, dug wells in the affected areas are to be substituted by borewells or tubewells to avoid the phreatic aquifer.

10. Creation of Sewage Traetment Plant (STP) in urban areas and construction of soak pit in rural areas should be given due importance to prevent ground water contamination.

11. Reuse of GW in urban area may be encouraged in urban areas particularly in Raipur town.

12. Detail investigation is required in Naya Raipur area to explore the possibility of Shallow potential aquifer zones within depth of 100m.

REFERENCES

- Aquifer systems of Chhattisgarh, Central Ground Water Board, Govt. of India, 2012
- Agrawal AP. (1981) GSI Sp.Publicatios No.3, pp- 135-140
- CGWB,(2011), Geophysical Report, North Central Chhatisgarh Region, CCGWB, Raipur
- CGWB,(2018), Ground Water Year Book, Chhattisgarh-2017-18, CGWB, NCCR, Raipur
- CGWB, (2018), State Chemical report ,Chhattisgarh-2017, CGWB, NCCR, Raipur
- CGWB, (2018) Ground Water Exploration, Chhattisgarh-2017, CGWB, NCCR, Raipur
- CGWB, (2019), Master Plan for Artificial Recharge in Chhattisgarh State.
- Dyanamic Ground water Resources of Chhattisgarh as on March 2020, North Central Chhatisgarh Region, CCGWB, Raipur.
- Dyanamic Ground water Resources of Chhattisgarh as on March 2017, North Central Chhatisgarh Region, CCGWB, Raipur.
- Hydrogeology of Chhatisgarh, 2020, State report, North Central Chhatisgarh Region, CCGWB, Raipur
- Karanth K.R. (1987) Ground water assessment development and management, the Tata Mc.Grow-hill publication, New Delhi
- Water Quality assessment for Drinking and Irrigation Purpose, Priyanka Tiwari, Indian J.Sci.Res. 13 (2):140-142, 2017.
- District Statistical Book (Raipur)-2020, Government of Chhattisgarh.

ANNEXURE-I: Exploration details in Raipur district

Sl. No	Block	location	Type	LAT	LONG	Depth	casing	Stratigraphy	Formation	Zone_encountered	Discharge	Draw down	Transmissivity__m2_day	Storativity
1	Dharsiwa	Shankarnagar	EW	21.2458	81.6167	198	14.7	Chandi	0.0-120.5 Chandi Fm 120.5-198 Gunderdehi Fm	14-16,37.3-39,114-116,154-156	3.5	50	2.64	
2	Tilda	TulsiNeora	EW	21.5358	81.8006	63.54	9.5	Chandi	Chandi Fm-limestone	12.20-63.59	0.4	3		
3	Dharsiwa	Mana	EW	21.1917	81.725	301.5	14	Chandi	0.0- 48.77 Chandi Fm 10.4-225.5Gunderdehi 225.5- 301.48 Charmuria	15.77-19.77,49.77-53.77	10	30	98.86	
4	Arang	Baroda	EW	21.2944	81.7306	296.95	13.7	Gunderdehi	Chandi limestone,	16-20,137.35 -140.5	2.83		105	0.0032
5	Dharsiwa	Taresar	EW	21.4056	81.7458	197	7.8	Chandi	00-118.00 Chandi Fm 118-197 Gunderdehi Fm	9.8-12.89,17.99-18.99,67.66-70.66,159.9-162., 169-172	5	18	121.7	
6	Dharsiwa	Rawabhata	EW	21.3167	81.6417	301.6	11.5	Chandi	0- 205 Chandifm& 205-301.6 Gunderdehi Fm	9525	0.2			
7	Dharsiwa	Telibandha	EW	21.2417	81.6833	135	13.25	Chandi	0.00-103 Chandi Fm 103.-135 Gunderdehi Fm	13.25, 14-19.75, 25.85-26.00, 129.5,131.5-133.5	10	25	18.4	
8	Tilda	Rajia	EW	21.525	81.8458	146.45	10	Chandi	0.0-48.95, Chandi Fm 48.95-124 Gunderdhi Fm 124-146.45 Charmuria Fm	9.35-12.35,16-18.45,24.0-39.75,48.95-76,114-114.75	2.25	18	8.22	

9	Tilda	Nawagaon	EW	21.3917	81.9167	301.48	10.4	Chandi	0.0- 10.4 Chandi Fm 10.4-225.5Gunderdehi 225.5-301.48Charmuria Fm	9.0- 10.4	10	30	98.86	
10	Dharsiwa	Shyamnaga r-II	EW	21.2347	81.6639	182.4	9	Chandi	0.0- 126.7 Chandi Fm 126.7- 182.4 Gunderdehi	14-16,182	3.5	25		
11	Dharsiwa	Saragaon	EW	21.3667	81.8167	281.81	8.21	Chandi	0-69.01 Chandi Fm 69.01-281.81Gunderdehi formation	27-28.5,166-168,190-195	1	29.37	2.47	
12	Abhanpur	Kendri	EW	21.1037	81.73	201	17.5	Gunderde hi	Shale	22-24.2,120-138	0.8			
13	Tilda	Mundpar	EW	21.4833	81.9042	300.4	8.7	Chandi	Chandi limestone and Gunderdehi shale	18-22, 68.8-72.4	0.33	26.22		
14	Dharsiwa	Kota	EW	21.2625	81.6167	199	11.7	Chandi	0.00-136.00 Chandi Fm 136-199 Gunderdehi Fm	16.8-18.60,19.8-21.0,68.4-68.6	2.1	50	6.15	
15	Abhanpur	Paragaon-II	EW	20.9875	81.8833	72	12	Charmuri a	Gunderdehifm shale and Limestone	14-16,35-50,				
16	Abhanpur	Urla	EW	21.0903	81.7542	290	7	Gunderde hi	Gunderdehifm shale and Limestone	15.32, 16.22,99-42, 206.50	1.75	50	6.02	
17	Arang	Mandir Hasaud	EW	21.2125	81.7694	300.5	34	Chandi	Dolomite/Limestone	13.4-15.41,65.5-66,146.0-149.0,209.0-213.3	0.8	40	2.1	

18	Dharsiwa	Sakri	EW	21.3222	81.725	160	6	Chandi		18.5	1			
19	Tilda	Khaprikhurd	EW	21.5792	81.8356	70.02	8.5	Chandi	Chandi Fm-limestone	17.22-25.10, 30.14-39.14	1			
20	Tilda	Kharora	EW	21.4	81.925	300.37	4	Chandi	0.0- 38.5 Chandi Fm 38.5 - 260Gunderdehi Fm	6.2-8,37.9-40.5 and 176-177	2	28.88	28	
21	Arang	Arang	EW	21.1856	81.9922	73.02	14	Charmuria	Gunderdehifm shale and Limestone	41.62-47.10,66.54-69.20	1.75	19.6	4.19	
22	Dharsiwa	Urla	EW	21.3167	81.5833	290	15.4	Gunderdehi	Chandi limestone, Gunderdehi shale	15--16	1.75	50	6.02	
23	Dharsiwa	Deori	EW	21.4662	81.6881	94.7	11	Chandi	Chandi limestone	14-20,30				
24	Arang	Bhansoj	EW	21.275	81.9125	147	13.5	Gunderdehi	0.0- 129 Gunderdhi Fm 129 -147 Charmuria Fm	21.7- 37	10	10	28.34	
25	Arang	Lakholi	EW	21.1958	81.9	300.6	5.5	Gunderdehi	0-142.5 Gunderdehi Fm 142.5-300.6 Charmuria Fm	22.7,40	3.1		55.87	
26	Tilda	Tilda	EW	21.5353	81.7837	304.4	17.17	Chandi	0.00- 288 Chandi Fm 288-304.4 Gunderdehi Fm	14-16,133-133.5	2	30.34	2.22	

27	Abhanpur	Abhanpur	EW	21.0583	81.7361	195.5	9	Gunderdehi	0.0- 195.5 Gunderdehi Fm	11-11.20,14.7-17.9, 18.8-18.9,37.05- 38 ,64.5- 65	3	20	17.9	
28	Tilda	Tilda	EW	21.5482	81.7991	60	15	Chandi	Chandi limestone	12--25,35	1.5	30		
29	ABHANPUR	Bedola	BW	21.1169	81.8866	60		Gunderdehi	Shale with Sandstone	18-20,50-60				
30	ABHANPUR	Pond	BW	21.0489	81.8984	160		Gunderdehi	Shale with Sandstone	15-20,45-50,60-64				
31	ARANG	Bhainsmudi	BW	21.3872	82.0759	115		Gunderdehi	Shale with Sandstone	12-15,40-50,70-78				
32	ARANG	Gullu	BW	21.2593	82.0209	60		Charmuria	Dolomite/Limestone	10-15,40-52				
33	Abhanpur	Abhanpur	PZ	21.0583	81.7389	100	11.5	Gunderdehi	Shale with Sandstone	10 to 11,30				
34	Abhanpur	Abhanpur	PZ	21.0583	81.7389	50	11.5	Gunderdehi	Shale with Sandstone	7.35 to 9.30, 10.70 to 13.60,38				
35	Arang	Arang	PZ	21.2125	81.9114	50	11.5	Charmuria	Dolomite/Limestone	10-12, 30				
36	Arang	Nawagaon	PZ	21.2189	81.8197	50	14.4	Chandi Limestone	Dolomite/Limestone	10-12, 30				

37	Dharsiwa	Dharsiwa	PZ	21.4083	81.6722	50	11.7	Chandi Limestone	Dolomite/Limestone	16-18, 34.35 to 41.00	1			
38	Dharsiwa	Mandhar	PZ	21.3389	81.7058	100	10.4	Chandi Sandstone	Dolomite/Limestone	8.40 to 9.00,32				
39	Dharsiwa	Mandhar	PZ	21.3389	81.7058	50	7.4	Chandi Sandstone	Dolomite/Limestone	8.40 to 9.00,35				
40	Dharsiwa	Pandarbhata	PZ	21.4628	81.6525	50	11.5	Chandi Limestone	Dolomite/Limestone	3 to 5,25 26	0.5			
41	Tilda	Kanki	PZ	21.4019	81.9881	50	5.5	Chandi Limestone	Shale with Sandstone	3 to 9,25	1			
42	Tilda	Tilda	PZ	21.5583	81.7889	50	17.65	Chandi Limestone	Dolomite/Limestone	6 to 9.00,35	2.5			
43	Dharsiwa	Pandarbhatta	EW	21.4646	81.6623	200.17	15.5	Chandi	Chandi		1			
44	Dharsiwa	Mohadi 1	EW	21.39386	81.67074	200.17	14.5	Chandi	Chandi		1			
45	Tilda	Adsena	EW	21.3437	81.8291	200.17		Chandi	Chandi		1.5			
46	Arang	Bhaisa	EW	21.4099	82.027	200.17	20.1	Gunderdehi	Gunderdehi		0.5			
47	Arang	Amethi	EW	21.22898	82.00527	200.17	16.5	Charmuria	Charmuria		1.5"			
48	Arang	Bodara	EW	21.2236	81.9451	200.17	8.5	Gunderdehi	Gunderdehi		Dry			
49	Arang	Reewa	EW	21.2239	81.8986	200.17		Gunderdehi	Gunderdehi		Dry			
50	Arang	Seoni	EW	21.2485	81.8636	200.17		Gunderdehi	Gunderdehi		0.5			
51	Arang	Charoda	EW	21.14084	81.94745	200.17		Gunderdehi	Gunderdehi		1.5			

52	Arang	Uperwara	EW	21.1197	81.7633	200.17	10.25	Gunderdehi	Gunderdehi		0.5			
53	Tilda	Chataud	EW	21.4991	81.8537	200.17	9	Chandi	Chandi		3.5			
54	Arang	Nishda	EW	21.50097	81.82466	178.31	9.15	Chandi	Chandi		4.5			
55	Arang	Nishda OW 1	OW	21.50097	81.82466	76	8.75	Chandi	Chandi					
56	Arang	Nishda OW 2	OW	21.50097	81.82466	162.07		Chandi	Chandi					
57	Tilda	Chatoud	OW	21.4991	81.8537	32.08		Chandi	Chandi					
58	Dharsiwa	R.G.I. -1	EW	21.2944	81.7306	202	15.9	Chandi	Chandi	16.30- 16.80, 61.00-61.50	1	38		
59	Dharsiwa	R.G.I.- 2	EW	21.2944	81.7306	202	11.65	Chandi	Chandi	63.00-63.50	0.37	31.13		
60	Dharsiwa	R.G.I.- 3	EW	21.2944	81.7306	202	11.5	Chandi	Chandi	10.00-10.50, 62.00-62.50	0.37	42.4		
61	Dharsiwa	R.G.I.- 4	EW	21.2944	81.7306	128.9	15	Chandi	Chandi	15.00-16.00, 84.00-85.00	4.5	29.54		
62	Dharsiwa	R.G.I- OW	OW	21.2944	81.7306	110.5	14.9	Chandi	Chandi	83.00-83.50	0.24	36.96		
63	Dharsiwa	R.G.I.- 5	EW	21.2944	81.7306	110.5	11.5	Chandi	Chandi	83.50-84.00	SEEPAGE	--		
64	Dharsiwa	R.G.I.- 6	EW	21.2944	81.7306	159.3	11.5	Chandi	Chandi	85.50-86.10	0.24	--		
65	Dharsiwa	R.G.I.- 7	EW	21.2944	81.7306	171.5	9.8	Chandi	Chandi	15.40-15.90	0.24	34.77		
66	Dharsiwa	RGI -I EW	EW	21.3072	81.6781	202.1	16.9	Chandi	DeongarChandi	15-32,61, 100.29	0.24			
67	Arang	RGI OW-II	OW	21.2944	81.7306	81.35	8	Chandi	Chandi limestone	12-15,36	12.93	1		
68	Arang	RGI OW-III	OW	21.2944	81.7306	81.55	8	Chandi	Chandi limestone	12-15,37	dry			
69	Abhanpur	Tuta PZ II	PZ	21.4194	81.7607	204.4	18	Gunderdehi	Shale	12-15,106 - 107.5,127.8 - 130	0.5-1.2			
70	Arang	RGI	EW	21.2944	81.7306	80.85	9.35	Chandi	Chandi limestone	12-15, 35	4.18	12	2.756	0.001455
71	Abhanpur	Tuta PZ III	PZ	21.4194	81.7607	150.2	18	Gunderdehi	Shale	12-15,48 - 49, 133.5 - 135	0.5-1.3			

72	Dharsiwa	RGI -III EW	EW	21.3006	81.6794	202	12.5	Chandi	DeongarChandi	64.7	1	31.13		
73	Arang	RGI OW-I	OW	21.2944	81.7306	89.85	8.85	Chandi	Chandi limestone	12-15,35	dry			
74	Abhanpur	Tuta	EW	21.1417	81.7554	200	17.25	Gunderdehi	Shale	32.33,55,72	1.2			
75	Arang	RGI OW-IV	OW	21.2944	81.7306	50.95	6.5	Chandi	Chandi limestone	13 - 14	13.14	0.5		
76	Arang	RGI OW-V	OW	21.2944	81.7306	62.9	8.3	Chandi	Chandi limestone	15.5-27,35	9.86	0.25		
77	Arang	RGI OW-VI	OW	21.2944	81.7306	62.9	8.3	Chandi	Chandi limestone	14-16,35	9.5	0.25		
78	Dharsiwa	RGI -V EW	EW	21.2981	81.6783	110.5	12.5	Chandi	DeongarChandi	14-16, 84	Seepage			
79	Dharsiwa	RGI -VI EW	EW	21.2981	81.6789	159.3	12.5	Chandi	DeongarChandi	14-16, 86	Seepage			
80	Dharsiwa	RGI,Daldalseoni	EW	21.2978	81.68	171.5	10.3	Chandi	Limestone	14-16,35				
81	Dharsiwa	RGI-IV EW	EW	21.2969	81.6767	128.9	16	Chandi	DeongarChandi	14-16, 85	4.5	42.42		
82	Abhanpur	Tuta PZ I	PZ	21.4194	81.7607	204.1	16.5	Gunderdehi	Shale	12-14,124 - 125, 167.5 -169	Water struckted-0.8 lps			
83	Arang	Baroda OW	OW	21.2944	81.7306	102	13.5	Gunderdehi	Chandi limestone	14-16, 53	8.9	0.35		
84	Arang	Baroda OW	OW	21.2944	81.7306	281.74	14	Gunderdehi	Chandi limestone	18.4,23,35	Negligible			
85	Dharsiwa	RGI- I OW	OW	21.2972	81.6764	110.5	15.9	Chandi	DeongarChandi	15-32,61,83.5	0.24	29.44		
86	Dharsiwa	RGI -II EW	EW	21.3	81.6869	202	12.65	Chandi	DeongarChandi	125.8	0.5	29.38		
87	Abhanpur	Kendri PZ II	PZ	21.5	81.78	155.3	14.3	Gunderdehi	Limestone	14-20,35	meagre			

ANNEXURE-II: Static Ground Water level details in Raipur district

Sl.No	Village	Block	longitude	latitude	altitude (m)	Pre	Post	Flu	RL_pre
1	Bajrangpur	Abhanpur	81.81	20.98	299	2.92	1.4	1.52	296.08
2	Nawagaon	Abhanpur	81.88	21.01	282	6.36	3.22	3.14	275.64
3	Gotiadih	Abhanpur	81.68	21.02	307	4.71	1.85	2.86	302.29
4	Abhanpur	Abhanpur	81.75	21.05	330	5.25	3.5	1.75	324.75
5	Abhanpur D	Abhanpur	81.74	21.06	321	14.1		14.1	306.9
6	Dhabadih	Abhanpur	81.87	21.27	280	6.38	3.08	3.3	273.62
7	Kendri	Abhanpur	21.1037	81.73	312	6.87	3.47	3.4	305.13
8	Kurra	Abhanpur	81.673532	21.42731	266	3.62	2.5	1.12	262.38
9	Manabasti	Dharsiwa	81.73	21.17	309	8.2	3.18	5.02	300.8
10	Dumartarai	Dharsiwa	81.69	21.2	299	8.86	4.18	4.68	290.14
11	Devpuri	Dharsiwa	81.68	21.21	295	10.2	3.7	6.5	284.8
12	Mandirhasud	Dharsiwa	81.77	21.22	312	11.91	3.4	8.51	300.09
13	Ravi Shankar University Raipur	Dharsiwa	81.58	21.24	279	6.23	3.67	2.56	272.77
14	Semariya	Dharsiwa	81.76	21.33	284	10.65	3.5	7.15	273.35
15	Mandhar	Dharsiwa	81.71	21.35	277	7.2	5.07	2.13	269.8
16	Sakara	Dharsiwa	81.66	21.35	276	18.54	10	8.54	257.46
17	Charauda	Dharsiwa	81.67	21.4	278	3.2	2	1.2	274.8
18	Dharsiwa	Dharsiwa	81.67	21.41	274	9.88	2.05	7.83	264.12
19	Saragaon	Tilda	81.81	21.37	276	5.61	2.38	3.23	270.39
20	Kharora	Tilda	81.92	21.39	301	9.23	3.2	6.03	291.77
21	Raita Satna Ni Para	Tilda	81.72	21.44	270	9.66	1.9	7.76	260.34
22	Pandan Bhata	Tilda	81.66	21.46	269	7.5	2.42	5.08	261.5
23	Chicholi	Tilda	81.86	21.47	308	13.26	2.51	10.75	294.74
24	Tarpongi	Tilda	81.69	21.49	271	6.52	1.82	4.7	264.48
25	Biladi	Tilda	81.78305556	21.57278	285	10	5.8	4.2	275

26	Math	Tilda	81.9026	21.395	299	7.79	2.45	5.34	291.21
27	Kanki New	Arang	81.95	21.39	302	8.54	0.87	7.67	293.46
28	Baihar	Arang	81.9492	21.1987	281	7.45	3.26	4.19	273.55
29	Bhatia	Arang	82.0348	21.4266	276	5.42	2.81	2.61	270.58
30	Ghivera	Arang	81.9752	21.3691	281	1.9	0.77	1.13	279.1
31	Godhi	Arang	81.7157	21.40444	297	6.14	4.2	1.94	290.86
32	Navagaon	Arang	81.8125	21.2234	303	4.52	3.22	1.3	298.48
33	Piperhatta	Arang	82.1012	21.6228	267	5.13	2.47	2.66	261.87
34	Ranisagar	Arang	82.03	21.28	270	3.52	0.82	2.7	266.48
35	Umaria station	Arang	81.87	21.2	291	8.36	2.41	5.95	282.64

ANNEXURE-III (A): Chemical Quality details of Shallow aquifer in Raipur district

S.NO.	Block	Location	Long	Lat	PH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	TH	Ca	Mg	Na	K	Si	Po4	TDS
						(µS/cm)	(mg/l)													
1	Arang	Umaria station	81.87	21.20	7.61	1474	0	61	170.4	105.2	0.1	0.54	465	112	44.4	90.9	1.3	8.4	0	884.4
2	Arang	Ghodari (Ghorari)	82.03	20.17	7.45	1016	0	226	71	80.8	72.6	0.18	340	120	9.6	53.5	1	8.9	0	609.6
3	Arang	Godhi	81.45	21.30	7.9	1047	0	275	74.55	61	77.8	0.26	355	110	19.2	40.5	37.9	9.9	0	628.2
4	Arang	Nawagaon	82.24	21.10	7.6	956	0	214	85.2	84.1	98.4	0.25	310	112	7.2	54.8	1.12	9.3	0	573.6
5	Abhanpur	Abhanpur	81.77	21.04	8.13	672	0	165	53.25	16.9	67.4	0.2	175	54	9.6	55.8	3.6	9.4	0	403.2
6	Abhanpur	Bajrangpur	81.81	20.98	8.03	577	0	250	24.85	17.4	67.4	0.4	135	26	16.8	80.1	0.98	9.5	0	346.2
7	Arang	Bhaisa	82.03	21.41	8.29	409	0	195	21.3	17.4	13.4	0.53	155	48	8.4	13.6	0.92	9.6	0	245.4
8	Arang	Bhatia	82.03	21.43	8.32	108	3	207	7.1	17.4	13.4	0.53	170	50	10.8	13.6	0.64	10.1	0	64.8
9	Tilda	Biladi	81.78	21.57	8.13	460	0	171	21.3	3.8	67.8	0.27	225	54	21.6	2.5	0.19	11.2	0	276
10	Tilda	Chicholi	81.87	21.47	7.71	1190	0	403	10.65	98.2	0.27	0.28	490	84	67.2	74	10	13.5	0	714
11	Dharsinwa	Chrauda	81.67	21.38	7.64	975	0	189	81.65	75.3	72.8	0.22	365	110	21.6	24.5	1.6	10	0	585
12	Dharsinwa	Devpuri	81.68	21.21	7.6	974	0	183	99.4	64.9	57.1	0.16	305	108	8.4	71.5	4.2	9.7	0	584.4
13	Darsinwa	Devri	81.68	21.47	7.45	1033	0	207	71	79.8	79.4	0.13	350	130	6	57	1.3	8.8	0	619.8
14	Dharsinwa	Dharsinwa	81.67	21.41	7.45	1032	0	220	78.1	79.8	89.4	0.2	355	114	16.8	56.4	1.2	8.8	0	619.2
15	Dharsinwa	Dumartarai	81.69	21.20	7.53	1028	0	183	138.45	28.4	10.9	0.78	335	86	28.8	69.4	1.7	9.4	0	616.8
16	Arang	Ghivera	81.98	21.37	7.76	498	0	244	14.2	15	11.2	0.38	180	50	13.2	29.3	0.56	11	0	298.8
17	Abhanpur	Gotiadih	81.68	21.02	7.63	1380	0	342	156.2	67.6	19.8	0.38	200	68	7.2	72.2	5.09	13.5	0	828
18	Kharora	Kanki	81.95	21.39	8.1	521	0	232	24.85	32.1	15.7	0.45	225	84	3.6	15.8	0.55	10.7	0	312.6
19	Arang	Kasrangi	81.98	21.37	7.97	489	0	250	17.75	16.9	10.5	0.71	155	40	13.2	35.2	0.89	11.2	0	293.4
20	Abhanpur	Kendri	81.74	21.10	7.8	359	0	189	17.75	3.7	6.9	0.39	150	44	9.6	18.2	0.42	10.6	0	215.4
21	Tilda	Kharora	81.92	21.39	8	406	0	122	39.05	19.6	0.1	0.39	90	20	9.6	40.6	1.36	9	0	243.6
22	Abhanpur	Kurra	81.78	21.11	7.98	583	0	305	28.4	13.9	0.1	0.38	130	34	10.8	77	1.05	10.6	0	349.8
23	Dharsinwa	manabasti	81.73	21.17	7.79	767	0	214	56.8	34	53.6	0.16	285	94	12	21.2	4.7	9.7	0	460.2
24	Dharsinwa	Mandhar	81.71	21.35	8.03	795	0	336	17.75	96.2	0.1	0.45	235	44	30	79.5	3.7	12.6	0	477

25	Tilda	Math	81.90	21.40	7.81	748	0	122	56.8	35.3	85.9	0.03	185	18	33.6	53.4	6.1	9.04	0	448.8
26	Arang	Narra	81.89	21.26	8.21	2152	0	262	248.5	406	64.9	0.53	630	222	18	150	34.9	11.3	0	1291.2
27	Palari	Palari	82.16	21.53	8.07	627	0	287	3.55	19.1	0.1	0.66	250	40	36	60.3	2.1	9.6	0	376.2
28	Tilda	Pandan Bhata	81.65	21.44	8.08	409	0	378	17.75	10.9	14.7	0.26	190	48	16.8	7.1	1.3	7.9	0	245.4
29	Arang	Piparhatta	82.10	21.62	8.14	2181	0	299	248.5	403	64.7	0.52	645	178	48	149	33.1	11.1	0	1308.6
30	Tilda	Raita (Satna ni para)	81.72	21.44	7.91	585	0	250	39.05	21.7	4	0.71	190	38	22.8	54	0.81	9.1	0	351
31	Arang	Ranisagar	82.03	21.28	7.8	649	0	287	31.95	11.1	1.5	0.41	225	54	21.6	43.7	0.94	8.5	0	389.4
32	Tilda	Saragaon	81.81	21.37	8.15	749	0	336	35.5	39.1	0.1	1.4	90	22	8.4	118.4	1.1	6.8	0	449.4
33	Dharsinwa	Semoriya	81.76	21.33	7.44	1010	0	207	74.55	76.9	77.2	0.2	330	104	16.8	53.6	1.1	8.9	0	606
34	Tilda	Tarpongi	81.69	21.49	7.88	571	0	336	24.85	5.8	1.2	0.16	270	60	28.8	7.9	0.7	11.5	0	342.6
35	Abhanpur	Nawagaon	81.75	21.05	7.86	374	0	171	10.65	4.2	3.6	0.22	155	40	13.2	15.3	0.6	10.6	0	224.4
36	Abhanpur	Kurru	81.51	20.02	7.84	366	0	189	10.65	6	14.7	0.25	150	44	9.6	11.9	1.2	8.7	0	219.6
37	Arang	Baihar	81.95	21.20	8.04	2345	0	421	376.3	258	41.1	0.59	575	168	37.2	169	98	18.7	0	1407
38	Dharsiwa	Dharsiwa	81.71	21.34	7.67	961	0	165	81.65	75.5	69.3	0.21	330	100	19.2	23.1	1.6	9.9	0	576.6

ANNEXURE-III (B): Chemical Quality details of deeper aquifer in Raipur district

Sl. No.	Location	Lititute	longitude	E.C. micro Siemens/C	pH	CO3	HCO3	Cl	NO3	SO4	Fe	ca	Mg	TH	Na	K	SiO	F
						(mg/l)												
1	Paragaon-I	20.988	81.883	426	7.5		238	18				40	18	175				
2	Turma	21.588	82.367	728	7.8	Nil	213	89				46		270				
3	Giroudpuri	21.615	82.564	326	8	Nil	183	7	1	5	0.5	36	9	110	20	4.7		
4	Sakri	21.322	81.725	433	8		268	7										
5	Bhatagaon	21.653	82.808	454	8.2	Nil	226	25	5.9	0	1.4	54	10	175	13.7	2.1		
6	Tundri	21.7	82.633	640	8	nil	250	49	Nd	46	0.3	22	4	70	#	1.7		
7	Tundri Ow	21.7	82.633	641	8.2	nil	262	49	Nd	32	0.3	24	5	80	#	1.7		
8	Pokhara	21.042	81.967	426	7.5		238	18				40	18	175				
9	Deobhog	19.888	82.65	624	8.2	NIL	165	35				40	24	200	80	4.2		
10	Kharora	21.4	81.925	286	9.3		165	11				40	12	150				
11	Gariyaband	20.617	82.083	127	7.4	NIL	61	11				12	5	50	9.2	1.4		
12	Rohra	21.733	81.938	1541	7.32	Nil	256	78				132	26	560				
13	Rohra OW	21.733	81.938	595	8.01	Nil	195	39				42	34	245				
14	Rohra OW	21.733	81.938	1072	7.95	Nil	146	57				76	47	385				
15	Deori	21.779	81.938	296	7.8		159	21				34	10	125				
16	Singarpur	21.824	82.019	649	7.62	nil	274	3				28	38	225				
17	Singarpur OW	21.824	82.019	207	7	nil		11				2	8	85				
18	Rajim	20.966	81.877	799	8.2	NIL	134	135				56	17	210	70	56		
19	Rajim OW	20.966	81.877	771	8.2		110	131				40	24	200	72	57		
20	Jidar	20.288	82.288	315	7.5		134	11				22	6	85				
21	Akalwara	20.909	82.14	91	8.3		24	11				8	4	354				
22	Raniparteva	20.97	82.151	327	7.4		189	14				38	10	135				
23	Chhura	20.811	82.211	181	7.3		98	7				20	5	70				
24	Bindra Nawagarh	20.396	82.182	213	7.1		110	18				18	8	80				

25	Paragaon	20.619	82.055	426	7.5		238	18				40	18	175				
26	Kochwai	20.662	82.086	436	7.5		195	35				36	28	205				
27	Dhawalpur	20.387	82.25	294	7.5		195	35				26	16	130				
28	Amdi	20.483	82.117	360	7.4		201	21				44	6	135				
29	Kendri			485	7.95	0	244	21.3	11	10.5		24	31.2	190	190	190	27.2	1.17
30	Pander Bhata			579	7.94	0	170.8	85.2	55.9	19.7		50	21.6	215	215	215	6.1	0.21
31	Mohadi -1			991	7.84	0	311.1	28.4	12.2	86.4		20	32.4	185	185	185	8.3	0.5
32	Chhataud EW			343	7.9	0	170.8	10.65	22.1	8.6		42	6	130	130	130	7.8	0.07
33	Chhataud OW			367	7.87	0	176.9	7.1	25.9	8.4		28	13.2	125	125	125	8.2	0.12

Photos